

Acta

Scandinavica

FOR: KNUD JANSEN, Copenhagen, Denmark

KSGAARD, Copenhagen

Vol. 49, No.

ACTA ORTHOPAEDICA SCANDINAVICA

is the official publication of the Scandinavian Orthopaedic Association

Acta Orthopaedica Scandinavica publishes original papers on orthopaedic surgery including Authors are also invited to publish follow-up notes and comments. Papers previously published in periodicals are not accepted

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Acta Orthopaedica Scandinavica is published bimonthly. The subscription price per volume of six at present Danish kroner 260.00 plus postage Dkr 26.00 (US \$ 48.65, £ 27.90 DM 110.15), advance. Prices are subject to exchange rate fluctuation.

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should indicate the subjects of the investigation. The abstract should comprise a brief and factual summary of the contents and conclusions of the paper, a pointer to any new information which it may contain, and an indication of its relevance.

It should be presumed that the reader has some knowledge of the subject but has not read the paper. The abstract should therefore be intelligible in itself without reference to the paper. It should only in exceptional cases exceed 200 words.

Key words 4-9 key words for indexing should be given by the author(s) together with the abstract. They should be placed in alphabetical order and when possible adjusted to the Medical Subject Headings of Index Medicus.

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Acknowledgements If applicable

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MICROCIRCULATION IN GRAFTED BONE

A Chamber Technique for the Study of Rabbit Bone Transplants

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A method enabling in vivo observations of the microcirculation in orthotopically transplanted bone in the rabbit is presented. It permits a repeated study of a well-defined bone tissue compartment before and after grafting to an autogenous or allogeneic recipient respectively. It yields information about the integration of the microvasculature and the resorptive and formative processes in bone remodeling during incorporation of grafted bone. In a series of experimental series, new capillaries were seen in the bone grafts after transplantation. No revascularization of preexisting graft vessels was observed.

Key words: animal experiments, bone, microcirculation, microvasculature.

Accepted 14

Biomicroscopy of the microcirculation in bone

Vital microscopy is the only technique that admits a direct and simultaneous registration of microvascular structure and function in a defined tissue compartment. Two refinements of the technique allow analysis of the intimate relationship between capillary structure, capillary topography and flow pattern at a resolving level of less than 10 microns (Branemark 1966). A transparent intravital microscope of bone tissue was first described by Branemark (1966). By grinding down the rabbit bone to a transparency Branemark was able to study microcirculation in the endosteal, subperiosteal layers and in the bone marrow. Earlier observations of the microcirculation in postnatal bone tissue and in the bone of heterotopical bone grafts had been made in a chamber technique (Branemark 1966).



chamber consisted of a titanium framework enclosing a light-conducting quartz glass rod, separated by a small gap from a cover glass. Regenerating bone marrow filled the gap during the 3-week period following installation of the chamber in the metaphysis of the rabbit tibia Brånemark *et al* (1964) presented a report on their observations of marrow regeneration and microvascular behaviour during this time interval Using a modified Brånemark chamber, McCuskey *et al* (1971) and McClugage *et al* (1971, 1973) presented a detailed analysis of the microcirculation in regenerating bone marrow with special reference to the haemopoietic tissue elements.

Apart from the earlier studies of heterotopically grafted bone in the rabbit ear chamber mentioned above, there are also more recent ones (Ezra-Cohn *et al* 1969, Sudmann 1975)

Biomicroscopy of the microcirculation in orthotopically grafted bone

No intravital study of microvascular reactions in bone grafted to skeletal sites could be found in the literature The studies on the microvascular anatomy of orthotopically grafted bone published to date have been out with histological examination of fixed specimens (Stringa 1957, Ferguson *et al* 1959, Kingma & Hampke 1964, Albrektsson 1971)

Of course, neither the histological studies nor the heterotropical chamber graft observations mentioned above permit any conclusions about the revascularization dynamics in grafted bone during different stages of "graft take" at a skeletal host site

The aim of the present report is to describe a bone chamber technique enabling *in vivo* observations of orthotopically transplanted bone

MATERIAL AND METHODS

Modifications to the Brånemark chamber were needed to cope with the special problems

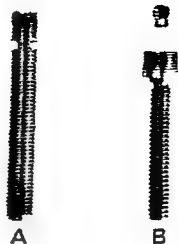


Figure 1 A Chamber type A for implantation in the rabbit tibia Chamber length 28 mm outer diameter 4 mm B Chamber type B for implantation in the rabbit tibia Chamber length 25 mm, outer diameter of the lower part 4 mm. The chamber type has a cover glass in a metal frame

associated with the transplantation procedure which demands limited dimension and maximum stability of the graft-chamber-graft bed complex Thus the bone transplantation chamber type A (Figure 1A) consists of a hollow externally threaded titanium cylinder with an outer diameter of 4 mm, containing two quartz glass windows (Vireosil[®]) separated by a 70–140 micron wide space The width of the space is defined by interposing a suture thread (Ethilon monofil 7 0, 6–0 100 microns, 5–0 140 microns respectively) and the glass rods are glued in position with Araldite[®] The type B chamber (Figure 1B) has, instead of the top glass rod, a cover glass placed in a removable metal frame The chamber type makes it possible to work with high magnification ($\times 23$ – $\times 55$) water immersion objectives.

The chambers were inserted in *in vivo* experiments, into the femur diaphysis, the diaphysis or the tibia metaphysis of male female Belgian hares or Half lop-eared rabbits at least 3 months of age

* The chambers were skilfully manufactured by Kukka Department of Anatomy University Göteborg

Installation of the chamber

The operations were carried out with the animals under general anaesthesia, maintained by i.v. injections of Nembutal Abbot at a dose of about 20 mg/kg body weight. Before the operation the animals were also given intraperitoneal injections of Valium, 1 mg/kg body weight.

Access to the chamber implantation site was gained by curved incisions through skin and fascia and by denudation of a circumscribed cortical bone area with the aid of a punch to cut the periosteum. The periosteum was removed only from the precise bone area to be perforated by the drill. A 3.0 mm well sharpened spiral drill was used to make a hole through the proximal cortex, the marrow space and the distal cortex of the bone. A 3.8 tap was used for

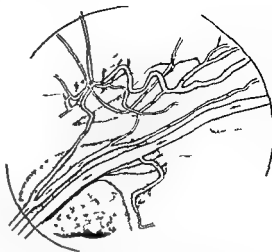


Figure 2 Low power view (drawing from photograph) of chamber space tissue. The bone trabeculae (white) are seen between "islands" of connective tissue (dark). Vessels of varying width are crossing the microscope field. Picture prior to transplantation, 7 weeks after chamber installation $\times 4$.

by saline irrigation was done to minimize the generated heat. Drilling was done with a speed of about 1,000 rev/min. The chamber and all drills and screws are of titanium. When the chamber was screwed into place, attention was paid to having the space in the proximal cortex oriented in the longitudinal direction of the bone, in the hope of achieving easier ingrowth of vascular tissue and bone into the observation area between the glass rods.

Registrations before grafting

Between 6 and 24 weeks after the implantation procedure the chamber was exposed via incisions in skin and fascia. The leg of the rabbit was supported on a stand mounted on a cross stage enabling careful adjustment of the position of the leg without undue compression of the soft tissues. The chamber was immobilized in a special holder securing horizontal positioning of the chamber space. Longitudinal movements of the leg with the chamber could be performed under controlled conditions by means of a micromanipulator. The bone and vessel architecture of the "future graft" was registered on video tape and film before carrying out the grafting procedure (Figure 2).

The biomicroscopical registrations were performed using a Leitz intravital microscope modified for the purpose. Objectives $\times 4$ – $\times 55$ together with eye-piece $\times 8$ were used. The microscope is provided with a magnification changer enabling zooming up to $\times 45$. To this set up a TV-camera with video tape recorder, a Vinten scientific film camera and a Nikon ESR camera were connected.

A Leitz stereomicroscope with binocular tubes $\times 25$ and objectives $\times 4$ and $\times 10$ was also used.

Transplantation of the incorporated chamber

All transplantations were performed a minimum of 6 weeks after the installation of the chamber at the donor site. The procedure was always initiated by preparing the host site. A surgical procedure similar to that performed when the chamber was installed was now carried out on the contralateral extremity. The hole in the bone was cut with a trephine drill with an outer diameter of 6.3 mm to make room for the excised cylinder containing the titanium chamber and an enveloping sheath of

to the prepared host site. The technique described guaranteed an exact fit between graft and graft bed. To ensure stability admitting vital microscopy at early intervals after grafting, the transplant was splinted to the host tibia using an osteosynthesis plate threaded on to the top of the chamber. This plate was constructed in such a manner as to minimize the contact with the periosteum as can be seen in Figure 4.

Registrations after grafting

At regular periods, beginning immediately after the grafting procedure, repeated intravital

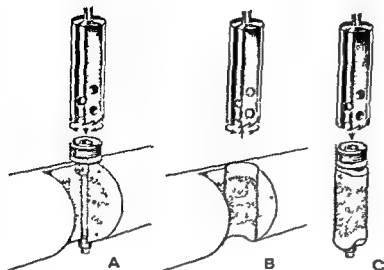


Figure 3 Schematic representation of the transplantation procedure. A Under saline cooling a trephine is used to cut out the chamber in surrounding bone and marrow. B The trephine chamber and graft is lifted out of the host bed (A bone window has been opened on drawings A and B to get better visibility). C Chamber and graft ready for implantation in a prefabricated hole in the contralateral extremity.

observations were performed under light general anaesthesia, the only limiting factor being the risk of anaesthetical complications. Microvascular and remodelling dynamics in the bone layer interpositioned between the glass rods have been registered up to 1 year after grafting. The sequences have been documented on film and video

tape permitting graphical measurements and morphometrical analysis of bone remodelling at different stages during the experimental period. It was also possible to measure flow velocity. At the end of the observation period contrast filling of vessels allowed for simultaneous microangiography and biomicroscopy. After sacrificing the animals the tissues were prepared for histology (Figure 5) and a comparison between intravital and histological findings was made.

OBSERVATIONS AND DISCUSSION

Implantation sites

Different implantation sites were tested. The rabbit femur diaphysis was found to be less suitable because of the risk of fractures. When the chambers were transferred from the ulnar diaphysis donor to an ulnar host site the contralateral extremity incorporation of the implant occurred without fractures. The radius, via the ossified interosseous membrane, acted in the same way as a biological splint (Albrektsson 1971) after the transected ulna. However, the forearm of the rabbit was found to be less suitable for the purpose of vital microscopy because of the problem of respiratory movements and the registrations. The proximal tibia was found to be the most suitable site. The medial facet of the tibial metaphysis is close to the skin surface, it is flat and its cortex is of

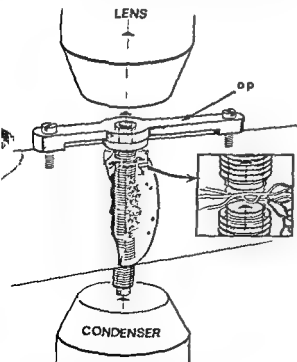


Figure 4 The chamber and graft in situ. Enlarged section shows the chamber gap with bone tissue and vessels. This space is between 70 and 140 microns wide. o p = osteosynthesis plate.



Figure 5 Histological section of the chamber space tissue 7 weeks after transplantation to a recipient site in the rabbit tibia. The section is taken from a part of the space where the bone post grafting by vital roscopy was proved to undergo resorption. The lacunae in the vicinity of the vessels contain osteocyte nuclei indicating that the tissue is vital. Cement lines separating these vital osteocytes from the non-vital parts indicate that the vital bone probably has developed after grafting $\times 180$

homogenous thickness facilitating a standardization of the implantation and observation procedures.

The bone graft

The graft consists of a cortical bone collar with the incorporated chamber. The part of the graft that could be studied with the vital microscope is found in the chamber space. As bone is a corticalized callus that has developed after chamber insertion.

In vivo observations on bone tissue

In about 90 per cent of the cases the

chamber space in our experiments was placed within the cortex to ensure better conditions for the study of the different events in the hard tissue components. With the space within the cortex one avoided fat cells in the test tissue. This gave better observation possibilities. The ingrowing tissue appeared in the form of bone ridges and a large amount of vessels of varying width (6–7 to 50 microns). Occasionally larger vessels (diameter 70–100 microns) were seen crossing the chamber gap, but these vessels did not give off any visible branches within the microscope field. Changes in flow direction and vessel pattern from the early stages of “graft take” to animal sacrifice were registered. The corpuscular flow rate could be determined by the flying spot technique (Bränemark 1959).

Contrary to Bränemark et al (1964), who registered the marrow circulation, the

Scattered “islands” of connective tissue in the bone made the identification of the bone ridges and their subsequent rebuilding easier

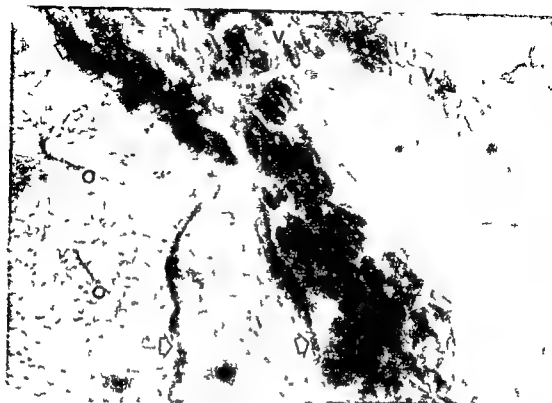


Figure 6 In vivo microscopic view of the bone and vessels in the chamber space 6 months after installation.

to register Bone apposition and resorption was analysed morphometrically. The resolution made it possible to identify osteocytes with canaliculae and to study individual red and white blood cells (Figure 6).

During the first week after transplantation it was possible to observe to and fro movements of blood corpuscles in pre-existing graft vessels. True circulation however was not observed in these vascular channels. Four to five days after the transplantation procedure, circulation was observed in newly developed vessels in the chamber space. These capillaries of 6–7 micron diameter were primarily confined to the connective tissue "islands" (see Figure 2) in the chamber space. During the following weeks there appeared a network of regenerating vessels adjoining the bone trabeculae. These vessels were of a calibre which amounted to between 6 and 40 microns. From the second week postoperatively, a few

vessels were observed to pierce the trabeculae. After revascularization, parts of chamber bone tissue underwent resorption, whereas other, also revascularized, bone remained structurally unchanged for follow-up periods of several months.

Further details of the revascularization bone remodeling processes will be described in a later report.

Chambers without bone tissue

In about 10 per cent of the chambers bone ingrowth had taken place 8 weeks after installation. In these cases either the chamber lacked primary stability or the implant was stable but had a glass space width of 70 microns. With this method 70 microns seemed to be the critical width to permit bone ingrowth. Undue movements of the chamber led to the production of an extensive

at stabilized the chamber after a prolonged ailing period of another 4 to 6 weeks. Bone growth however did not take place in spaces implants lacking primary stability (4 cases) instead of bone the glass space contained inactive tissue with a limited amount of uniformly sized vessels (around 10 microns) ranged in a rather parallel fashion.

ACKNOWLEDGEMENT

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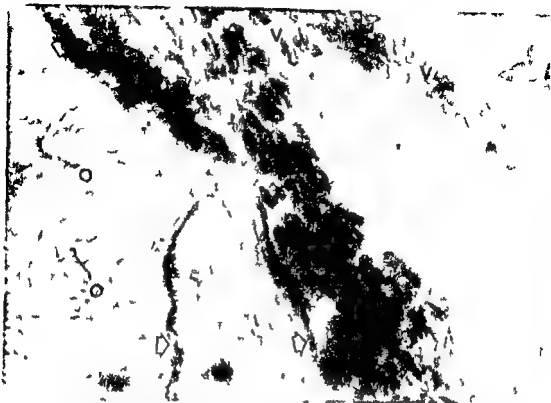


Figure 6 In vivo microscopic view of the bone and vessels in the chamber space 6 months after installation before transplantation. The arrows indicate trabecular bone edges. Arterioles or venular vessels often seen close to bone trabeculae. V = Venule with erythrocytes. O = Osteocyte lacuna with canal cul. Photograph in Leitz intravital microscope objective. Leitz $\times 55$ NA 0.65.

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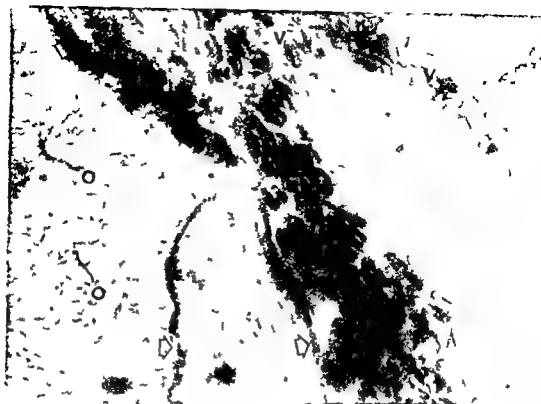


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Further details of the revascularization and bone remodelling processes will be described in a later report.

Chambers without bone tissue

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Table 1 The patients and the total hip replacements studied

Age, sex, and body weight of patient	Disease for which total-hip replacement performed	Type of total-hip replacement	Duration of implantation	Reasons for removal	Skin sensitivity tests
33 years Female 50 kg	Osteoarthritis	McKee-Farrar	7 years	Severe bone loss	Negative to Co
72 years Female 59 kg	Osteoarthritis	Ring Thompson	3 years	Severe bone loss	Negative to Ni and Cr slight response to Co
62 years Female 71 kg	Osteoarthritis	Ring Thompson	3½ years	Slight bone loss	Negative to Ni and Cr
56 years Female wt. not known	Osteoarthritis	McKee-Farrar	6 years	Bone loss and proven sensitivity to Co and Cr	Positive to Co and Cr
33 years Female wt. not known	Osteoarthritis	McKee-Farrar	10 months	Developed a sinus within three months - at no time was there any infection	Positive to Ni and Cr

elements above atomic number 11. In specimens where a closer examination of the metal/tissue interface is required, the implants are coated with a thin layer of carbon to prevent destruction of the tissues by the beam of electrons.

Other metallurgical methods of analysis

In addition to scanning electron microscopy with EDXA and light microscopy other methods were used to examine the implants. Carbon arc emission spectroscopy was used for the semi-quantitative chemical analysis of the body tissues. The monomer content of PMMA bone cement was determined by monomer extraction and gas phase chromatography. The PMMA-bone cement was examined by electron probe microanalysis which uses the wavelength dispersive analysis of X-rays after bombardment of the sample with electrons, in a scanning electron microscope. A scanning electron microanalyser can detect elements with atomic numbers as low as 4 (carbon), compared with 11 (sodium) for EDXA.

Histological examination

Tissue removed at operation was examined using conventional staining and light microscopy.

Bacteriological examination

The fluid, pultaceous material, and tissues about the implants were examined for sterility using plate and broth cultures.

Skin sensitivity tests

Solutions of 2 per cent cobalt chloride, 1 per cent potassium dichromate and 2 per cent nickel sulphate were applied to the skin for 48 hours. The results were read at 48 hours. An eczematous reaction was read as a positive result, and an eczematous reaction with induration was read as a strongly positive result.

FINDINGS

Specimens from Patient 1

Clinical findings and naked eye observations

A McKee-Farrar total-hip replacement was removed, 7 years after its implantation, from a 68-year-old female patient. Radiographic examination had revealed widespread loss of bone substance in the femur and pelvis about the left hip. At the time of its surgical removal it was observed that, apart from the presence of a small amount of joint fluid, the femoral component was firmly held in the bone, whereas both the acetabular component and the screws were loosening. On extraction of the acetabular component from the PMMA-bone cement, it was noticed that the cement/metal bond was extremely firm. Similarly the one screw that was in the cement was tight. The fibrous tissue layer, which was immediately against the polished areas and the distorted and polished spikes of the acetabular

pelvic surface was coloured green. The tissue layer about the screw was also coloured green but only in three places in juxtaposition to the end of the screw, the first few (polished) threads of the screw and the slot of the screw head. A green crystalline film or deposit was present on the articular surfaces of both the acetabular cup and the femoral head. On the pelvic side of the acetabular cup there were areas which showed polishing and some spikes were distorted. The screws also showed areas of distortion and polishing on their tips and on the first few threads which were screwed directly into pelvic bone.

Histological examination Sections from the tissue around the implant showed abundant lymphocytes in a poorly cellular fibrous matrix. Prominent foreign body giant cells surrounded spaces once occupied by material now dissolved out of the section which in this situation might be indicative of corrosion. There was also much amorphous debris and fragments of either necrotic (dead) bone or plastic.

SEM examination The sections of tissue and PMMA bone cement associated with the

femoral stem of the Co-Cr-Mo C all implant were examined using the analytical and optical modes of the scanning electron microscope. Spicules of bone could readily discerned and identified in the tissue. Figure 1 shows the tissue as revealed by the scanning electron microscope in which pieces of bone substance are evident. The analytical mode, the same field of view identifies calcium shown in Figure 2. Superpositioning of the two figures revealed the specific areas of bone. No trace of cobalt was detected in the tissue using these techniques.

Close examination of the inner surface of the PMMA bone cement from around the femoral stem by scanning electron microscopy and EDXA revealed no evidence of metallic elements from the implants on the surface of the PMMA bone cement. Further examination of the PMMA bone cement with the aid of the electron probe microanalyser on both surfaces (that is adjacent to the femoral stem at the metal/cement interface and at bone/cement interface) showed small quantities of Cr and Mo on the side adjacent to the metal/cement interface and no Cr or significantly more Mo at the bone/cement interface. No trace of Co was found in another sample of PMMA-cement from the same area.



Figure 1 Tissue removed from Patient 1 embedded and examined in the optical mode of the scanning electron microscope. The arrows point to embedding medium (EM) and the bone tissue (BT).



Figure 2 Tissue removed from Patient 1 embedded and examined for Ca in the analytical mode (EDXA) of the scanning electron microscope. The bright areas show Ca enrichment.

The PMMA-cement removed from this patient was found to contain 3 per cent monomer, whereas 5 per cent monomer was found in a sample of PMMA-cement as prepared during a revision operation and examined for monomer at 7 days.

Figure 3 shows schematically the appearance of the articulating surface of the acetabular component. There are four distinct areas, an inner surface showing wear, a green crystalline deposit, a thin ring of green protenaceous material, and an outer zone of wear. The green crystalline deposit observed by scanning electron microscopy is shown in Figure 4 which reveals the layering and its crystalline nature.

Table 2 lists the analytical results obtained from the samples of this deposit on the EDXA attachment. Molybdenum and cobalt were not detected. These figures are only to be interpreted semi-quantitatively. However, the presence of Ca, Cr, P and S in approximately equal proportions suggests a mixed crystal of chromic sulphate and calcium phosphate (apatite). This is consistent with the view that chromium is not easily soluble in the body fluids, in contrast cobalt and molybdenum more readily dissolve and become dispersed throughout the body.

A closer examination of one of the screws showed mild corrosion or etching, both of the tip (Figure 5) and of the first few threads which were screwed directly into the pelvis. A corrosion pit and areas of etching were found on the first thread and Ca was detected in the bottom of this corrosion pit. This finding suggests that the type of attack present in the acetabular component and the screws is similar. It should also be noted that the screws

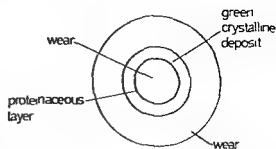


Figure 3 Schematic diagram of articular surface of the acetabular component removed from Patient 1 (not to scale). Note the four distinct areas as recorded in the text.

were not manufactured by the commercial supplier of the prosthesis so that the chemical reactions observed are likely to be specific to the Co-Cr-Mo-C alloy, rather than to the mode of manufacture.

A comparison of the type of attack observed at the screw tip (Figure 5) with the metallographic sections of the screw and the tip of the femoral stem showed that the distance between corrosion pits was of the order of microns whereas the grain, or crystalline, sizes of the screw and the stem were hundreds of microns and thousands of microns, respectively - that is the attack was general rather than intergranular. The screw has a cored equiaxed grain structure whereas the femoral stem has a large grained dendritic cored structure, both structures are typical of Co-Cr-Mo-C alloys.

Discussion

The pathological and metallurgical findings from this patient together with the findings from Patients 2 and 3 suggest that dissolution of the Co-Cr-Mo-C alloy had occurred in life. This corrosion would lead to the ions of Co, Cr, Ni and Mo being absorbed locally into the tissues. Because Co, Ni and Mo ions appeared to be readily soluble in body fluids, they would be dispersed throughout the body. In contrast at least some of the Cr ions were not dispersed and have clearly combined with calcium and phosphate ions (possibly from the bone) and sulphate ions (possibly from the

Table 2 EDXA of the green crystalline deposit

Element	Count level (sample 1)	Count level (sample 2)
P	1217	1489
S	782	1172
Ca	1000	1143
Cr	972	943

pelvic surface, was coloured green. The tissue layer about the screw was also coloured green but only in three places in juxtaposition to the end of the screw, the first few (polished) threads of the screw, and the slot of the screw head. A green crystalline film or deposit was present on the articular surfaces of both the acetabular cup and the femoral head, on the pelvic side of the acetabular cup there were areas which showed polishing and some spikes were distorted. The screws also showed areas of distortion and polishing on their tips and on the first few threads which were screwed directly into pelvic bone.

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blood) to produce the mixed crystal of chromic sulphate with some form of apatite

This interaction between chromium and calcium may have altered the balance of bone formation/resorption locally and contributed to the loss of bone substance from the femur and pelvis. It is possible that osteogenesis in this patient was particularly susceptible to the presence of such ions in her tissues. Moreover, bone necrosis may also have occurred due to the metallic ions released from the prosthesis, necrosis would also lead to local loss of bone substance

These hypotheses supplement the findings of other workers on metal sensitivity (Evans et al. 1974), and the increased cobalt and chromium contents in the hair, blood and urine of such patients (Coleman et al. 1973)

The chromium sulphate/apatite crystals could explain the green colouration observed

by orthopaedic surgeons both on Co-Cr-Mo-C alloy implants and in fibrous tissue adjacent to such implants.

Specimens from Patients 2 and 3

Clinical findings The next two specimens are similar in that they were both Ring-Thompson total-hip prostheses with cemented femoral stems in female patients. In Patient 2, the prosthesis was removed after 3 years, when the patient showed widespread loss of bone substance in the femur and pelvis. In Patient 3 there was a slight loss of bone substance in the pelvis three and a half years after implantation. Initially the wear and corrosion characteristics are examined

Prosthesis wear Scanning electron microscopy of the articulating surface of the acetabular



Figure 6 Scanning electron micrograph of the articular surface of the acetabular component removed from Patient 2. Note the broad scratches resulting from corrosion.

eventual loss of bone both in the pelvis and femur is a by-product of the further dissolution of the wear products or the prostheses. The chemical reactions observed appear to be specific for the Co-Cr-Mo-C alloys used. Moreover these reactions possibly lead to the presence of resorbed bone adjacent to the prostheses.

The next part of the paper considers the responses observed in the presence of two McKee-Farrar total hip replacements in patients with proven sensitivity to Co, Cr or Ni.

Specimens from Patient 4

Clinical findings. A McKee-Farrar total-hip replacement was removed 6 years after its implantation from the right hip of a 62-year-old female patient. The patient had recently

complained of pain and radioisotope examination had revealed slight bone loss. Tests had revealed that the patient was sensitive to Co and Cr. At operation a large amount of bone loss in the acetabulum was noted.

SEM examination. Scanning electron microscopy of the articulating surface of the acetabular component revealed the presence of rod-like particles embedded in the tissue that surrounded the prosthesis (Figure 8). The particles were 1–2 μm long and 0.2 μm in cross section. Table 5 shows results obtained with the EDXA. There is enrichment of Cr within the particles. These particles have been observed from time to time in the last few years in our laboratory both on bone plates and on prostheses removed from patients. They are usu-

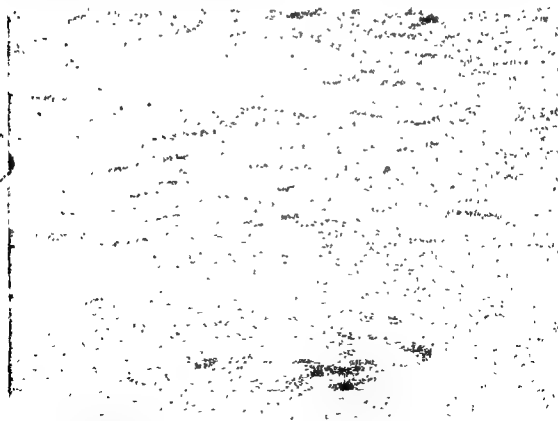


Figure 8. Scanning electron micrograph of collagenous tissue and rod-like particles. Note the size of the particles, 1–2 μm long \times 0.2 μm in cross section.

Table 5 EDXA of the particle

	Energy	Integral
layer	2.30 (S)	491
	5.42 (Cr)	1262
particle	2.30 (S)	909
	5.42 (Cr)	2899

Co levels were present in each specimen.

Table 6 Semi quantitative chemical analyses of tissue and fluid removed from Patient 4

Element	Tissue adjacent to acetabular component	Fluid in capsule
Ba	500-1700 ppm	<0.02 ppm
Ca	>1%	200 ppm
Co	<50 ppm	<1 ppm
Cr	170-500 ppm	<1 ppm
Fe	500-1700 ppm	20-60 ppm
K	>1%	>200 ppm
Mg	500-1700 ppm	20-60 ppm
Mo	<2 ppm	<0.2 ppm

associated with implant corrosion. Other workers (Vernon-Roberts 1976, personal communication), have observed similar particles and they are only found on implants from patients of proven sensitivity to one of the constituent elements of the Co-Cr-Mo-C alloy used to fabricate the prostheses.

Tissue Table 6 lists the results of carbon arc emission spectroscopy of adjacent tissue and fluid removed at the time of operation. A substantial amount (up to 500 ppm) of Cr was recorded in the soft tissue which lined the outer surface of the acetabular component.

Discussion

The association of the particles with implant corrosion and metal sensitivity suggests that they could be of immunological origin. Figure 9 outlines the possible formation mechanism, via chelation of the metal ion with protein in the tissue to produce an antigen which would lead to an antibody response. It is therefore likely that the particles are

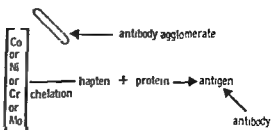


Figure 9 Antibody agglomerate formation mechanism

antibody agglomerates produced as a consequence of the patient's sensitivity to one of the constituent metals in the alloy, in this instance Cr.

Specimens from Patient 5

Clinical findings This patient in her early fifties with severe bilateral osteoarthritis had a McKee-Farrar artificial hip joint inserted in her left hip. Two weeks after the operation the wound was healed, the patient was free from pain on the operated side and was walking satisfactorily. Within 3 months the patient developed a sinus, both the sinus discharge and the sinus tissue were sterile on culture. Subsequent dermatological tests showed that the patient was sensitive to Ni and Cr. An inconclusive result was obtained from the test for Co. The prosthesis was removed 10 months after operation after which the wound healed without any difficulty.

Where there is minimal tissue response to the presence of Co-Cr-Mo-C alloys the colour of the soft collagenous tissue, which forms within a few days of insertion and remains throughout the implant's use, is white. In this instance there was a grey deposit present in the articulating parts of the prosthesis, on the neck of the femoral component and the outer surface of the acetabular component.

SEM examination The grey deposit immediately adjacent to the outer rims of the acetabular component was examined under the optical and analytical modes of the scanning

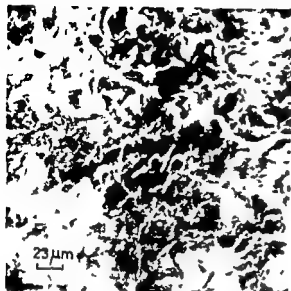


Figure 10 Grey deposit attached to the acetabular component removed from Patient 5 examined in the optical mode of the scanning electron microscope

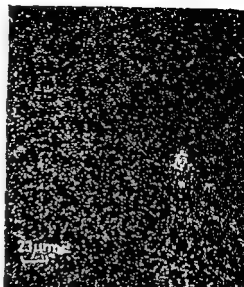


Figure 11 Grey deposit attached to the acetabular component removed from Patient 5 examined in the analytical mode (EDXA) of the scanning electron microscope. The bright spots show Cr and Co enrichment

electron microscope. Figure 9 shows the appearance of the deposit and Figure 10 shows the analytical mode of the same field of view identifying Cr and Co. There are areas of Cr and Co enrichment.

Discussion

The patient's metal sensitivity in this instance produced an unusual tissue response. This tissue became enriched in Cr and Co and a sinus formed. Nothing short of complete removal of the prosthesis was successful in getting the wound to heal.

CONCLUSIONS

The findings from this study suggest

- (1) Corrosion of Co-Cr-Mo-C alloy implants occurs in life. The presence of this corrosion and the products of such corrosion can lead to loss of bone substance through either Co ion or Cr ion release.

- (2) The occurrence of metal sensitivity possibly induce an immunological response or sinus formation.

ACKNOWLEDGEMENTS

The authors wish to acknowledge with gratitude the help and encouragement of the members of the Harlow Wood Orthopaedic Hospital, the City Hospital, Nottingham, the Royal Hospital, Chesterfield, and the Medical School, University of Nottingham.

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STRESS FRACTURES CAUSED BY PHYSICAL EXERCISE

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A series of 142 stress fractures caused by sporting activities and physical exercise is presented. 121 fractures occurred in athletes and 21 in non-competitive sportsmen. Distance runners presented with 68 fractures, skiers 12, sprinters 10, orienteering runners 9, vaulters 3, and football players 3 fractures. Athletes engaged in other events had fewer stress fractures: 76 fractures occurred in the tibia, 26 in the metatarsal bones, 20 in the fibula, 5 in the femoral neck, 4 in the femoral shaft, and 2 in the metacarpal bones, lower pubic arch and sesamoid bones of the first MTP-joint. There was one fracture of each of the following: the humeral shaft, the ulna, the vertebral arch of L 5, the tarsal navicular and the proximal phalanx of the fifth toe. The treatment was generally a pause in training for 4-6 weeks, on the average. Running caused most of the stress fractures, the rest followed jumping exercises. The athletes mostly developed stress fractures during a period of alteration from one training session to another or during the preparation period close to the competition season. Joggers usually developed stress fractures 2-4 months after the beginning of regular training.

Keywords: fracture, stress fracture, athletic injuries, physical exercise

Accepted 30 viii 77

Although the German army physician Breithaupt as early as 1855 described stress fracture in soldiers, stress fractures in athletes were not mentioned until several decades later (Pirker 1934, Baetznier 1936). With the growing interest in competitive sports and the development of sports medicine, more stress fractures have been found to occur in athletes (Burrows 1948, Devas & Sweetnam 1956, Devas 1969, Blazina et al 1962, Arndt 1969, Brubacker & James 1974, Clement 1974, Apel & Metze 1975, Haluzicky & Szab 1975, McBryde 1975). Stress fracture develops in a bone, without trauma, when it is rhythmically bending as a result of constant and long-lasting movement, muscular forces and mechanical stress. In both athletes and soldiers the same basic factors have been

found to be the probable causes of stress fractures. These are, for example, the circumstances, methods and amount of training, skeletal framework, muscle fatigue and physical condition (Bernstein & Stone 1944, Weber 1967, Devas 1975). Gilbert & Johnson (1966) found fewer cases of stress fractures in army recruits who were in good physical condition and who had previously participated in sports. Although the physical condition as well as the strength of the skeleton of athletes is, in general, better than in soldiers (Nilsson & Westlin 1971), stress fractures occur nevertheless. Thorough studies of stress fractures in athletes are not available.

The aim of this study was to describe the stress fractures found in Finnish athletes and non-competitive sportsmen. Special attention

was paid to the connection between the intensity and amount of training and the appearance of stress fractures.

PATIENTS AND METHODS

During the years 1968–1976, 142 stress fractures in athletes and non-competitive sportsmen were recorded.

The median age of the patients was 22 years (range 10–51 years, Figure 1). Seventy-seven per cent of them were between 16 and 29 years. There were 25 women (17.6 per cent) and 117 men (82.4 per cent).

Seventy fractures occurred on the right and 72 on the left side.

The series consists of 55 middle- and long-distance runners, 12 skiers, 10 sprinters and hurdlers and 9 orienteering runners (Table 1). Non-competitive sportsmen sustained 21 fractures; they were all joggers.

Most fractures occurred in April (20 per cent). Runners usually developed fractures in spring and autumn, joggers in autumn, and skiers during the snowless season. Most women's fractures appeared in autumn.

The number of patients with stress fractures amounted to about 1 per cent of the total number of athletes attending the clinic.

Condition of training

In only 13 cases was the stress fracture a consequence of training other than running. In 52

number

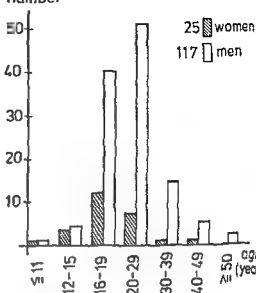


Figure 1 Age and sex distribution of patients with 142 stress fractures

long-distance runners (76 per cent) the amount of training preceding the appearance of the fracture was noted. On the average they had been running approximately 110 km/week. Runners ran less than 100 km/week and eight than 150 km/week. One athlete ran 200 km/week. The skiers and orienteering runners did not receive the same amount of training. They were trained over a distance of about 30–40 km. Most of them had been practising regular

Table 1 Relation between sporting activity and stress fracture site

Sports	Bone										
	Tibia	Metatarsal bones	Fibula	Femoral neck	Femoral shaft	Pubic arch	Metacarpal bones	Sesamoid bones	Humeral shaft	Ulna	Tarsal navicular
Track and field	50	19	10	4	1				1		
Jogging	7	5	5		1	2					1
Skating	6	1	1	1	2			1			
Orienteering	7										
Ball games	4	1	1							1	1
Power events							2				
Gymnastics											
Cycling			1					1			
Total	76	26	20	5	4	2	2	2	1	1	1

*Mike
Sain*



Figure 2 Gamma camera scintigram of a stress fracture in the upper tibia of a distance runner. The fracture was not visible in radiograms

exercise for only a few months before the onset of the symptoms of the stress fracture

Symptoms and diagnosis

The main symptom of the stress fracture was pain, which at an early stage appeared only after training, then during it, and later, even when walking. The pain was at first diffuse in character, later localized. A characteristic symptom was pain caused by a pace- or stride shock. A palpable callus was often preceded by local swelling and tenderness.

In most cases repeated radiograms were necessary to confirm the diagnosis. Initially a delicate fissure line might be seen, but usually the fracture became detectable only after callus formation. Tomography proved useful in the early stage. Radioisotope-scanning (Sr^{90} , Tc^{99}) was positive before the radiological changes (Figure 2) which took 2-6 weeks to show up. Isotope activity was increased for 1 year following healing of the fracture.

Location

Ninety-five per cent of the stress fractures were found in the lower extremities and 5 per cent elsewhere in the skeleton (Figure 3). The relation between the site of fractures and the sports event is shown in Table 1.

Seventy-six fractures occurred in the tibia (53.5 per cent). Most of them were located in the proximal and distal thirds of the shaft, whilst only two fractures appeared in the middle third. The fracture line was visible in about 40 per cent of the cases. Callus developed postero-medially in fractures of the upper and lower third (Figure 4), and anteriorly in the middle third fractures. The uppermost fractures did not become visible (as an increased internal density in the radiograms) until 2 months after the onset of symptoms. Usually the fracture extended through one cortex only and in a few cases through the whole bone.

Ten out of 26 stress fractures in the metatarsal bones were in both the second and the third bone, four were in the fourth and two in the fifth bone. Most of these fractures were located in the shaft.

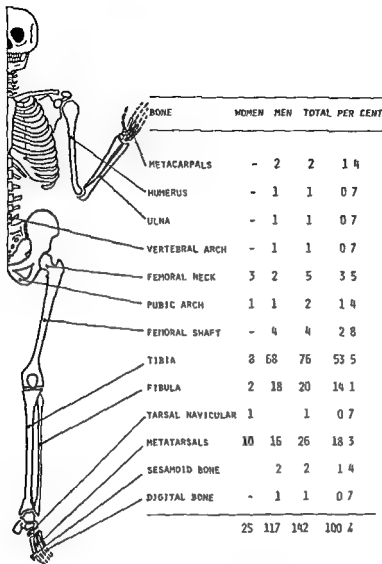


Figure 3 Topographical location of stress fractures

and the neck. A fusiform callus was characteristic of these fractures in radiograms.

In the fibula 16 of the 20 stress fractures were located just proximal to the tibio-fibular syndesmosis. All these fractures were caused by running. Other fibular fractures followed jumping exercises.

Three distance-runners, one skier and one high-jumper presented with a stress fracture of the femoral neck. Three of them were women. The fractures were located infero-medially (Figure 6). X-ray changes developed 2-4 months after the onset of symptoms.

In two athletes sesamoid stress fractures occurred in the medial bone of the first MTP-joint. These fractures were easiest to observe in

tangential projections. Symptoms disappeared without treatment in about 11 months.

Spondylolysis of the fifth lumbar vertebra appeared in a previously symptom-free judoka. Initial radiograms were normal. The diagnosis was confirmed with oblique projections tomography 6 months later. The scintigram (Tc-99m) was also positive. During rest, symptoms disappeared. After 8 months the patient gradually returned to full training and soon afterwards won the third prize in the Finnish Judo Championships.

Special features

Six partial stress fractures transformed to complete fractures during training or competition.

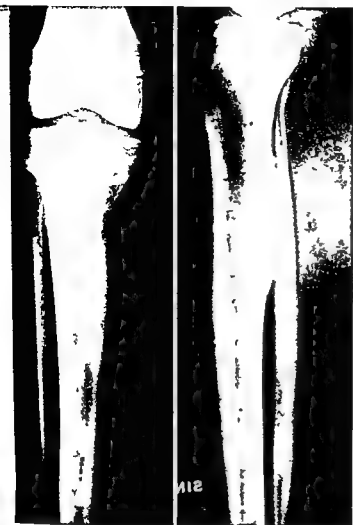


Figure 4 Stress fracture of the upper tibia in a distance runner. A large callus is located posteriorly.

Two of them were in the femoral shaft, two in the third metatarsal bone, one in the tibia, and one in the humerus.

Four female and eight male athletes presented with more than one fracture. Seven of them had two consecutive stress fractures in different bones with an interval of approximately 11 months. Four women had two simultaneous fractures in different bones. Three consecutive stress fractures occurred in the tibiae of one long-distance runner. He was the only patient with a renewed stress fracture in the same bone.

Treatment

Generally the treatment was limited to a pause in training lasting for 4–6 weeks. Normal activity

was allowed. A longer pause was needed in stress fractures of the upper tibia, femoral neck and shaft, pelvis, ulna and vertebral arch. In fractures of the femoral neck the pause lasted about half a year and in the fracture of the vertebral arch 8 months.

A plaster cast was used in five cases. Four of these were complete fractures. Eight patients needed crutches.

Two patients were treated by open surgery because of complete femoral shaft fractures.

Sick leave was required in 14 cases (9.8 per cent).

DISCUSSION

Stress fractures are caused by a certain disproportion between the load and the strength



Figure 5 Stress fracture of the lower tibia in a sprinter. A Radiogram 3 weeks after the onset of symptoms. Oblique fracture just visible with thickening of both the anterior and posterior cortices.

of the musculo-skeletal tissues. The bones do not have enough time to adapt to increasing and long-lasting mechanical stress. In the series presented above the amount of training of the endurance runners was 110 km/week, which is not particularly high, as modern endurance runners often run 250 km/week. The fitness joggers did 30–40 km/week which is also quite a moderate amount of training. A common aetiological feature was a change in either the quality or the quantity of training. This was most conspicuous in joggers, who usually sustained stress fractures 2–3 months after the beginning of a regular training programme, just as soldiers get stress fractures

in the months immediately following recruiting (Gilbert & Johnson 1966, Wilk & Katz 1969). Similarly the seasonal variations are related to the changes in the training programmes. Among the 12 patients sustained more than one fracture, individual unknown factors may be of significance. Running technique and psychological disposition may be important.

In the differential diagnosis both the differential bone diseases, tumours etc., and other over injuries of athletes must be considered (De Luca 1975).

There were only nine children in the series. They all exercised significantly more than



3 Radiogram after 6 weeks Oblique stress fracture clearly demonstrable

children on the average. This rare occurrence of stress fractures in children was also noted by Griffiths (1952), Berkebile (1964) and Zweymüller & Frank (1974).

The frequency and location of stress fractures differ in various materials of army recruits and athletes (Blazina et al 1962, Darby 1967, Devas 1975). In the present series more than half of all fractures were located in the tibia. The same observation was made in previous Finnish series of soldiers' stress fractures (Söderlund 1952, Salmela 1969). This high relative proportion of fractures in the tibia has never been reported elsewhere in

the world. On the other hand, fracture of the distal fibula is rare although it is considered common in athletes (Burrows 1948, Devas & Sweetnam 1956, McBryde 1975). No calcaneal stress fractures were found. The general use of good sports shoes may explain this.

Generally the only treatment needed is rest from sporting activities. After 4–6 weeks break the athletes could gradually increase their training. The risk of a stress fracture becoming complete is particularly great in fractures of the femoral shaft and neck (Provost & Morris 1969, Bargren et al 1971).



Figure 6 Three month-old stress fracture of the femoral neck in a female skier

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FRACTURES OF THE OLECRANON

Analysis of 37 Consecutive Cases

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This study is based on 37 consecutive cases of fracture of the olecranon treated during the period 1973-1975. The average follow up time was 1.5 years. The treatment was operative in all but two of the cases. Superficial post-operative infection occurred in three cases and in three cases internal fixation failed due to porous bone. The transverse fractures healed more satisfactorily than the comminuted ones. A short post-operative immobilization of 3 weeks or less gave the best results ($P < 0.05$). In a comparison of methods cerclage combined with two Kirschner wires gave better results than cerclage alone.

Key words: elbow injuries, fracture fixation

Accepted 16 viii 77

As a rule, fractures of the olecranon are treated operatively (Weber & Vasey 1963, Luther & Schultz 1968, Bakalm & Wilppula 1971a, Colton 1973, Labitzke 1975), with the only exceptions being undislocated fractures and fractures in children (Scheuba & Unger 1970, Newell 1975). Many operative methods of treatment have been developed. Wire loop fixation, intramedullary nailing (Kuntscher 1967), percutaneous Kirschner wires, the Zuelzer nail (Zuelzer 1958), plating, screw-fixation (Müller et al 1963), excision of the fragment with reinsertion of the triceps tendon (Bakalm & Wilppula 1971b) and tension wiring (Weber & Vasey 1963, Labitzke 1975).

The purpose of this paper was to find out which of the methods employed in this series gave the best results and what other factors influenced the results.

MATERIAL AND METHODS

The series is based on 37 consecutive fractures of the olecranon treated in the Surgical Hospital,

University Central Hospital, Helsinki, during the period 1973-1975. The age and sex distribution of the patients is shown in Figure 1. Female patients were more numerous (23/14). All the male patients were under 60, whereas 13 of the female patients were over 60 years of age.

The fracture was often sustained in a fall. All fractures were dislocated except for one in a 15-year-old boy. Fifteen of the fractures were transverse, five oblique and 18 comminuted. One patient had a fracture of both olecranons. All fractures were intra-articular and they were complicated in three cases. One of the fractures was associated with luxation of the radial head. None of the patients showed any neurological or vascular deficit in the upper extremity.

To evaluate the size of the proximal fragment the joint cavity was divided into degrees. The distribution of the fractures is shown in Figure 2. In almost all of the cases the fracture fell within the sector 40-100° (34/37).

All but two of the patients were treated operatively. The above-mentioned undislocated fracture in an adolescent was treated with a plaster of Paris cast. The other patient suffered from severe rheumatoid arthritis. An olecranon fracture on the contralateral side had been treated operatively, but the osteosynthesis had failed due to severe osteoporosis.

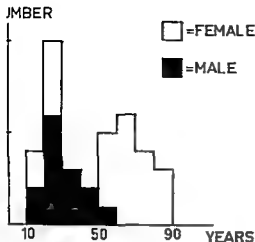


Figure 1 Age and sex distribution of patients with olecranon fractures

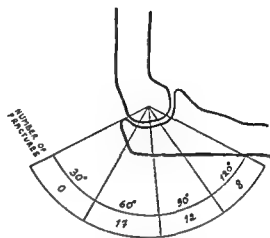


Figure 2 Distribution of the site of 37 olecranon fractures in the semilunar notch

Most of the fractures (24) were treated surgically within nine hours of the patient's arrival at the casualty department. In 19 cases the primary treatment was internal fixation with two Kirschner wires and cerclage (Table 2). A unique method was used in almost all of the cases (35). The operation time ranged from 30 min to 1 hour (mean 1 hour).

The average duration of hospitalization was 5 days (range 1-11 days) and that of plaster immobilization was 22 days (range 0-44 days). In 22 cases the internal fixation material was later removed under local anaesthesia.

The patients were requested to attend a follow-up 2 years after the operation. For evaluation of the clinical results the subjective and objective results were combined and scored as follows.

Excellent=symptom-free, motion equal to the intact side

Good=occasional pain or restriction of motion less than 10°

Fair=occasional pain and restriction of motion less than 30°, or over 30° with no pain

Poor=occasional pain with restriction of motion over 30°

No statistical significance was studied with the chi-square and *t* tests.

RESULTS

At follow-up 20 out of 35 operatively-treated patients were entirely symptom-free, 10 had

occasional pain or pain after strenuous exercise, and two were not evaluated because of rheumatoid arthritis. Loss of rotation was found in two patients, 15° in one and 90° in the other. Loss of extension-flexion was seen in 20 patients: 1-10° in seven, 11-30° in six and over 30° in seven patients. In 28 cases the radiological result was good, whereas in the remaining seven there were clear post-traumatic arthrotic changes.

Patients under 50 did better than the older ones and the results of the men were better than those of the women, although these findings were not significant. Transverse fractures healed, as was expected, better than the comminuted fractures (Table 1). When the immobilization time was 3 weeks or less the result was significantly better than when plaster was used for more than 3 weeks (Table 3), regardless of the degree of comminution.

Three patients developed a superficial infection and failure of the osteosynthesis was observed in another three. In the first case of failure of the internal fixation, the primary result was good, but the wire loop behind the Kirschner wire loosened. The patient was treated with cortisone for rheumatoid arthritis and she had a superficial infection post-

Table 1 Effect of fracture type on results

Fracture type	Results				Total
	Excellent	Good	Fair	Poor	
Comminuted	6	3	7	2	18
Transverse	5	4	4	0	13
Oblique	2	0	2	0	4
Total	13	7	13	2	35

Table 2 Effect of methods on results

Method	Results				Total
	Excellent	Good	Fair	Poor	
2 Kirschner wires and cerclage	8	6	6	1	20*
Screw	4		3	1	8
Simple wire loop	1	1	4		6
Resection	1				1
Total	13	7	13	2	35

* The results of one patient were not evaluated because of severe rheumatoid arthritis

Table 3 Effect of immobilization on results

Immobilization (days)	Results				Total
	Excellent	Good	Fair	Poor	
0-21	9	6	4	1	20*
22-44	4	1	9	1	15
Total	13	7	13	2	35

* $P < 0.05$

operatively. The second failure was an elderly woman with osteoporosis, the screw used for the osteosynthesis pierced the proximal fragment. In a second operation a new osteosynthesis was performed with two Kirschner wires and a wire loop, resulting in arthrosis. In the third failure, the osteosynthesis was performed with a simple wire loop which cut through the proximal fragment.

Patients without associated injuries were off work between 21 and 236 days (mean 77 days).

DISCUSSION

The age distribution is similar to that reported in previous papers (Luther & Schultz 1968, Scheuba & Unger 1970). In this material, the patients over 60 were women. When the fracture line passed through the corono process or distal to it, it was not considered fracture of the olecranon (Raubert & Kopf 1955). This is in contrast to the classification used by some other authors, for example Luther & Schultz and Scheuba & Unger.

The clinical results were similar to those presented by Bakalm & Wilppula (1971a, b), however, the number of poor results was smaller in the present series. The results were better for the male than for the female patients, the explanation is probably the higher incidence of osteoporosis and the more advanced age of the female patients. The restriction of mobility in the present series was smaller than in the materials presented by Luther & Schulitz (1968) and Scheuba & Unger (1970). They put greater emphasis on conservative treatment. The eight patients remained in the series of Weber & Vasey (1963) all had a restriction of under 10°. Bakalm & Wilppula suggest that their relatively high incidence of limitation of movement might be attributed to the relatively long average duration of immobilization (6 weeks in operatively treated cases). Immobilization for over 6 weeks seemed to have an unfavourable effect on the results. At present, there is a trend towards short immobilization, for example, Weber & Vasey recommend a plaster cast for only 4 days. In the present series the average duration of immobilization was 22 days.

In one case the head of the screw cut through the proximal fragment. A washer might have prevented this occurring in the rotator bone. Stable internal fixation can be achieved with a screw in transverse and oblique fractures of the olecranon. It may not always succeed in comminuted fractures, too long or too short a screw will lead to a failure, and too thick a screw may split the fragment and dislocate the fracture.

In conclusion, we suggest that internal fixation with two Kirschner wires and cerclage according to Weber & Vasey (1963) should be

the method of choice in treating fractures of the olecranon in most cases. A period of immobilization of 3 weeks or less is recommended.

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FRACTURE OF THE RADIAL NECK IN CHILDREN

A Long-Term Follow-up Study of 43 Cases

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A series of 43 radial neck or head fractures in children was analysed with respect to the type of fracture and whether conservative or surgical treatment had been employed. Thirty-seven patients were examined after a follow-up period of 1-18 years (average 8 years). Tilting of the radial head, the angle of the radius and the size of the radial head were measured roentgenologically to evaluate any growth disturbances. The results were good in 24, fair in five, fair in six and poor in three cases. All but two of these patients had an angulation of the radial head of 30° or more. The result was good in 20 and 23 patients who were treated conservatively because the angulation was less than 30° after reduction. In fair and poor cases the function was impaired by the limitation of motion. Disturbances in growth were generally slight; the enlargement of the radial head was observed in 16 cases in the follow-up.

Key words: fracture, radial neck, children, long term follow-up

Accepted 16 VIII 77

Fractures of the radial neck or head are relatively uncommon in children. The frequency varies between 4.5 and 10 per cent of all fractures in the elbow region (Blount 1955, O'Brien 1965, Henrikson 1969, Tachdjian 1972). A fall on the outstretched arm compresses the capitellum against the outer side of the head of the radius, tilting and displacing it outwards and forwards. The valgus strain can cause an avulsion of the ulnar epicondyle (Dunlop 1935), a rupture of the ulnar collateral ligament or capsule or even a fracture of the olecranon or the upper shaft of the ulna (Jeffery 1950). In about half of the cases of radial neck fracture the proximal radial epiphysis is also involved (Jones & Esah 1971). When the fracture line is lower, a greenstick fracture of the neck of the radius may occur (Jeffery 1950, Watson-Jones 1955). According to the authors mentioned above

fracture of the radial head rarely occurs in children.

The following complications have been described in the literature:

- 1) New bone formation and deformity of the radial head with enlargement (Blount 1955, Fielding 1964, O'Brien 1965, Jones & Esah 1971).
- 2) Avascular necrosis of the radial head and/or premature fusion of the epiphyseal plate resulting in a shortening of the radius. Cubitus valgus deformity may be the result (Jeffery 1950, O'Brien 1965, Henrikson 1969, Jones & Esah 1971). On the other hand Rees & van Gorder (1963) did not find a shortening of the radius in spite of premature fusion of the upper radial epiphysis.
- 3) Fibrous adhesions or crossed synostosis between the radius and ulna limiting the rotation mobility (Fielding 1965).

A combination of two or more of these applications, resulting in most cases in a pleasing deformity.

In our series we have analysed the long-term results of radial neck or head fractures in children treated conservatively or surgically. Special attention was given to any growth implications and the causes of possible restrictions of motion. The prognostic radiological criteria in the evaluation of the final results and the indications for surgical treatment are discussed.

PATIENTS AND METHODS

Patients

The present series consists of all fractures of the

1957-1975 Of the total number of 43 patients, 37 were examined by the authors in 1976. The remaining six patients were followed up as outpatients until the fracture had healed and the motion of the elbow was satisfactory, but because a personal after-examination was lacking, these six patients were excluded from the follow-up study. The ratio of boys to girls was 18/25. The age of the patients at the moment of injury varied from 5 to 14 years with an average of 10 years. The highest frequency of fractures was found in the

night.

Type of fracture

There were no open fractures. There were 21 cases of fracture-separation of the proximal epiphysis and 21 cases of greenstick fracture of the neck with angulation. The remaining case was a small marginal fracture of the radial head.

The tilting of the radial head or fragment was radial in 42 cases and medial in only one case. In 25 cases the radial head was tilted anteriorly and in nine cases (23 per cent) posteriorly. In seven cases the radial head was completely displaced with total separation of the epiphysis.

Associated injuries

Associated injuries of the elbow were found in 34 per cent (16/43). Five patients had an avulsion fracture of the ulnar epicondyle. Four patients had fractures of the olecranon, one patient a fracture of the upper part of the shaft of the ulna. Posterior luxation of the arm occurred in two cases. Avulsion fractures of the coronoid process, intra-articular avulsion fracture of the lateral proximal part of the ulna (insertion of the ligamentum annulare) and fracture of the capitellum of the humerus were found in one case each. There was partial radial palsy in one case but it regressed completely within 8 weeks. The nerve was not explored. There were no vascular complications in this series.

Treatment

Closed reduction was done in 11 cases, ten cases with angulation less than 25° were immobilized without reduction. Of the total number of patients 32 per cent (14/43) were treated surgically. Open reduction was indicated when the angulation of the radial head could not be corrected up to 25° in both planes by closed means. An operation was also performed in cases of a complete epiphyseal separation or a dislocated marginal fragment of the radial head. There were only two exceptions to these indications. One case with radial tilting of only 20° was operated on, because of radial and anterior displacement of about one half of the bone diameter. One case treated elsewhere was first seen in our hospital 4 weeks after the injury. The remaining case with radial tilting of 65° was left and no operation was performed.

Fixation of the radial head was done with catgut in 10 cases and a Kirschner wire through the radioulnar joint in three cases. A small marginal fragment was removed in one case. One reoperation was performed in a case of failure of the reduction position after the first operation, in which the totally anteriorly displaced radial head was fixed with catgut sutures through the soft tissues.

Plaster immobilization was used in 42 cases and a cuff and sling in only one case. The average time in plaster was 33 days, range 15 to 61 days. There were no passive physical exercises.

Methods of investigation

Tilting of the radial head was measured on both the antero-posterior and lateral projections of both arms on the date of injury, at the end of treatment and at the follow-up. Measurements were made to an accuracy of 5°. The differences in these angles compared with the values of the healthy arm were

registered. The size of the radial head was also measured at the follow-up. Differences of more than 1 mm between the fractured and non-fractured sides were recorded. The primary radiographs of all 43 patients and those of the 37 patients followed up were compared.

At the clinical after-examination the carrying angle and the lengths of the radius and the ulna were measured. If there was any suspicion of a difference in the lengths of the two arms, the lengths of the radius and ulna were measured roentgenologically. The range of motion of the elbow was measured on both arms.

Follow-up examination

The follow-up period ranged from 1 to 18 years with an average of 8 years. The age of the patients at follow-up varied between 8 and 19 years, average 17 years.

The end result was to be judged good, if restriction of any of the movements of the elbow joint was less than 10° compared with that on the healthy side, or the difference in the carrying angle (CA) was less than 10°. Values from 10 to 30° were graded fair, and the end result was classified as poor if restriction of any of the movements was more than 30°.

RESULTS

In this series the radial angulation of the normal contralateral radial head varied between 11 and 15°, average 12.5°. The angulation of the normal radial head forwards or backwards varied from 10° forwards to 5° backwards, being 3.5° forwards on average.

The end results according to the criteria mentioned above (Table 1) were good in 65 per cent (24/37), fair in 27 per cent (10/37), and poor in 8 per cent (3/37). The type of

treatment in the various classifications of primary angulation is also seen in Table 1. Five of the ten fair cases and all the three poor cases were treated surgically. Out of eight operatively treated cases with total primary displacement the end result was good or fair in five cases.

Correction of angulation

The spontaneous correction of the angulation of the radial head was generally 10° or less during the period of growth, with an average 9.3°.

Complications

There were three poor results in this series: two cases of synostosis between the radius and ulna with complete limitation of rotation and one case of aseptic necrosis of the radial head. In the latter case the arm was dislocated posteriorly and the radial head totally displaced anteriorly. Because of redislocation of the radial head, reoperation was performed but an aseptic necrosis occurred. The radial head was excised, but fibrous adhesions limited rotation to 60°. The same type of injury with posterior dislocation was present in another operatively treated case resulting in radio-ulnar synostosis (Figure 1). Resection of the synostosis and the radial head resulted in 80° of rotational movement. In the second case of synostosis operative reduction failed with an anterior and radial displacement of the radial head of about half of the diameter of the radial neck. A large mass of callus at

Table 1 End results at the follow-up

Primary angulation (degrees)	Good		Fair		Poor		Total
	Non-op	Op	Non-op	Op	Non-op	Op	
<30	14	1	3	0	0	1	19
30-60	5	1	0	4	11	0	10
>60	0	3	1	2	0	2	8
Total	19	5	4	6	0	3	37
	24 (65 %)		10 (27 %)		3 (8 %)		



Figure 1A A 14-year old boy Fracture of the left radial neck with epiphyseolysis and total anterior displacement Lateral projection There was also posterior dislocation of the elbow which was reduced in emergency room



Figure 1B A good position of the fracture after surgical reduction



C On the twenty-third day when the plaster was removed signs of myositis ossificans can be seen.



ossitis ossificans developed. A resection operation similar to that performed in the other case of synostosis is planned for the end of the growth period in this case. In 43 per cent (16/37) enlargement of the radial head was observed. The increase was from 3 to 14 mm. The limitation of rotation amounted to more than 30° in three of these patients, while a limitation of 15–30° was observed in seven patients. In three patients it was less than 15° and in three patients there was no limitation of motion. In ten cases open reduction was performed. The distribution of the primary displacement of these 16 cases was almost the same as in the three placement groups.

Myositis ossificans (MO) was found in 32 per cent (14/43). In most cases the signs of MO on the radiograph were situated in front of the proximal part of the ulna corresponding to the ulnar insertion of the supinator muscle. In seven patients were treated surgically. In five of these and in four cases treated conservatively the signs of MO had disappeared at the follow-up and the end result was good. In the remaining seven cases slight changes indicative of MO were observed on the radiographs at the follow-up, with limitation of motion lowering the end result grading to fair or poor. However the combination of synostosis, or necrosis of the radial head, and MO was the main cause of poor results in this series.

In two cases the radial head was excised and in four other cases the radius was 3–9 mm shorter than on the healthy side. The cubital carrying angle varied between 5 and 25°, the difference being 10° or less than on the healthy side. The average carrying angle was 25° on the healthy side, and 14.8° on the injured side.

DISCUSSION

The reported incidence of other injuries in the elbow region associated with fracture of the radial neck is between 12 and 30 per cent (Jeffery 1950, Reidy & van Gorder 1963, O'Brien 1965, Jones & Esah 1971). In our

series it was 34 per cent. Posterior luxation of the arm was found primarily in two of the cases later classified as poor and seemed to indicate a poor prognosis in fracture of the radial neck.

An enlargement and deformity of the radial head were found in 43 per cent (16/37) of our cases. This phenomenon was reported by O'Brien (1965) in 12 per cent (15/125) and by Jones & Esah (1971) in 13 per cent (4/30). The higher incidence in our series may be due to the strict criteria used for measuring the radial head in both projections. The deformity of the radial head generally caused slight limitation of rotation.

The serious complication, avascular necrosis of the radial head, seems to occur quite infrequently and generally in less than 10 per cent of cases. Jeffery (1950) reported one case of excision of the radial head (1/24). Reidy & van Gorder (1963) reported one aseptic necrosis of the radial head (1/30) and Jones & Esah (1971) three cases (3/34). This complication occurred in one case (1/37) in our series.

A premature fusion of the epiphyseal plate may be expected in epiphyseal injuries of the radial neck (Jeffery 1950). O'Brien (1965) reported this complication in as many as 40 out of a total of 125 cases. However this complication seldom resulted in marked shortening of the radius and/or cubitus valgus, and was of no clinical significance (Reidy & van Gorder 1963, O'Brien 1965, Henrikson 1969, Jones & Esah 1971). O'Brien (1965) found shortening of the radius in only five cases (5/125). We also agree that this complication poses no serious problems. This may be due to the fact that the radius grows mainly from the distal epiphysis.

Fibrous adhesions or crossed synostosis between the radius and ulna limit the rotation mobility (Fielding 1964). O'Brien (1965) found synostosis in six cases (6/125), Henrikson (1969) in three cases (3/55) and Jones & Esah (1971) in one case (1/30). This severe complication was present in two cases (2/37) in our series. Resection of the synostosis and the radial head was performed later, at the end

of the growth period, in one case, resulting in satisfactory rotation

Myositis ossificans changes did not cause serious problems. In half of the cases with MO the calcifications disappeared, if they remained the motion was slightly limited.

Henrikson (1969) and Jones & Esah (1971) reported poor results in 15 and 23 per cent of their cases. Using similar criteria we found poor end results in 19 per cent.

In order to prevent the complications mentioned above, Stankovic et al (1975) suggested operative treatment when tilting amounted to 20° or more. Other authors prefer conservative reduction in cases of tilting between 30 and 60°, and reserve open surgery for cases with tilting of more than 60° (Jeffery 1950, Blount 1955, O'Brien 1965, Jones & Esah 1971, Sharrard 1971, Tachdjian 1972).

In conclusion we suggest the following treatment guidelines:

1 In cases with angular displacement of less than 30° the need for reduction is questionable. A plaster or sling immobilization for 2–3 weeks is sufficient.

2 Cases with angular displacement between 30 and 60° should be treated by closed reduction. If this is not successful, surgical reduction is indicated.

3 Cases with displacement of more than 60° usually require surgical intervention.

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REDUCTION OF DISPLACED SUPRACONDYLAR FRACTURE OF THE HUMERUS IN CHILDREN BY MANIPULATION IN FLEXION

JLFOUOH M EID

Sixty-one children with posteriorly displaced supracondylar fractures of the humerus were treated by manipulation with the elbow flexed 40°-60°. This

being used. Redisplacement occurred in only 8.2 per cent of the patients and in none of these was it severe enough to justify remanipulation.

Key words: supracondylar fracture, humerus

Accepted 5 x 77

ny different methods have been described for the treatment of displaced supracondylar fractures of the humerus in children. Similarly, methods of fixation vary widely. This paper reports a method for reduction and fixation which has proved easy to utilize, and is more reliable and safer than the other methods described.

MATERIAL

Sixty-one children with posteriorly displaced supracondylar fracture of the humerus (Grade III fractures in which there is no contact between the fragments) were treated by the author and followed during the period from 1970 to 1976. There were 43 boys and 15 girls. Their ages ranged from 3 to 15 years. Treatment was carried out 3 to 48 hours from the time of injury. In seven patients, previous attempts at reduction had been made and in four of these reduction was tried more than once. In six patients the elbow region was grossly swollen.

Associated injuries included

- 1) *Skin and soft tissues* Bruising on the medial side of the elbow was present in 42 patients

(68.9 per cent). In 18 of these (42.9 per cent) the skin was perforated by the sharp lower end of the proximal fragment.

- ii) *Vascular injuries* One patient presented with a cyanotic hand and forearm (1.6 per cent). In 15 patients (24.5 per cent) the radial pulse was not palpable but there was normal capillary circulation in the nail beds.
- iii) *Nerve injuries* Six patients (9.8 per cent) had nerve injuries. Two of them showed median nerve compression and in four the radial nerve was involved.

METHODS

Method of reduction

Reduction was carried out under general anaesthesia as soon as the child was considered to be fit. Traction was applied to the forearm, with the elbow flexed 40°-60° against counter traction from the axilla (Figure 1). This was continued until the upward displacement was corrected. Lateral displacement was then corrected by lateral pressure between the thumb and fingers of one of the operator's hands, the other hand maintaining traction (Figure 2). With traction still maintained the posterior displacement was corrected next. The

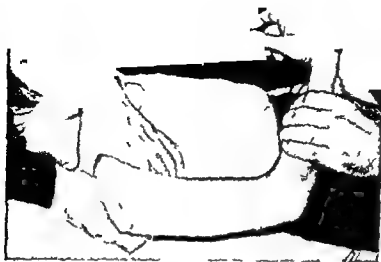


Figure 1 First step manipulation reduction of upward displacement



Figure 2 Second step in manipulation reduction of lateral displacement



Figure 3 Third step in manipulation reduction of posterior displacement

limb of the surgeon's manipulating hand was placed behind the olecranon, pushing it and the distal fragment anteriorly, while the fingers of the other hand pushed the front of the proximal fragment posteriorly (Figure 3). At this stage, rotational displacement should have been corrected by the tenseness of the tissues around the fracture (Harnley 1968). If this had not occurred, the distal fragment was rotated externally until the epicondyles were re-aligned with the epicondylar ridges of the proximal fragment (McLaughlin & Thomson 1959). Following the above steps, and in the presence of clinical evidence that the fracture had been reduced, the elbow was flexed as far as possible without obliteration of the radial pulse, usually to 120°.

During the initial stages of reduction, traction was carried out with the forearm in pronation (Lawwright 1962). Towards the end of manipulation and before flexing the elbow, the forearm was abducted on the arm and brought into pronation (Blount 1955).

In four patients (6.4 per cent), three of whom had had manipulations twice previously, swelling of the elbow rendered immediate reduction impossible. Skin traction and elevation was applied for 48 hours after which reasonable reduction was achieved by manipulation.

Assessment of reduction

Clinically the fracture was considered reduced when

- The concavity seen on the posterior aspect of the elbow before reduction had disappeared.
- The elbow could be flexed to greater than a right angle without obliteration of the radial pulse.
- The "point" of the elbow was felt to be in the line of the long axis of the humerus or even in front of it.
- The epicondyles on the distal fragment were re-aligned with epicondylar ridges on the proximal one.

Radiologically the fracture was considered reduced when all elements of displacement were corrected both in the anteroposterior (axial infero-superior - Clarke 1964) and lateral views (Figure 2a and b).

Assessment of the carrying angle

Clinically the carrying angle was considered restored when

- The epicondyles were re-aligned with the epicondylar ridges of the proximal fragment.

- The relation between the three bony prominences of the elbow, to the long axis of the humerus, as seen from behind with the elbow flexed, was comparable to that on the normal side ('The visual method of Smith' 1960). This indicates the position of the distal fragment in relation to the proximal one.

Radiologically, the carrying angle is restored when the cortices of the two fragments are continuous with each other in the absence of any rotation or angulation of the distal fragment.

Fixation

Reduction was maintained by zinc oxide adhesive plaster, binding the flexed forearm to the arm just above the elbow. A collar-and-cuff holds the elbow in the optimum position of flexion (Figure 5). The limb was then placed under the clothes to prevent the child from using his arm. This was continued for about 3 weeks. Flexion of the elbow was increased on the second or third day in patients who presented initially with grossly swollen elbows.

RESULTS

Assessment of results

The follow-up period ranged from 8 months to 6 years, the average time being 39 months.

- Clinically* - on completion of follow-up
 - Excellent. Normal appearance and function of the elbow joint with up to 5° change in the carrying angle and 5° limitation of extension.
 - Good. Change in the carrying angle of up to 5-10° but not beyond cubitus rectus, and up to 5-15° limitation of extension.
 - Poor. Any alteration in shape or function of the elbow greater than the above limits.
- Radiologically* - post-reduction X-rays.
 - Excellent. Correct anatomical alignment with no visible displacement.
 - Good. No more than 3-4 mm lateral or posterior displacement, but with normal alignment.
 - Poor. Any rotation or angulation deformity persisting even if slight.

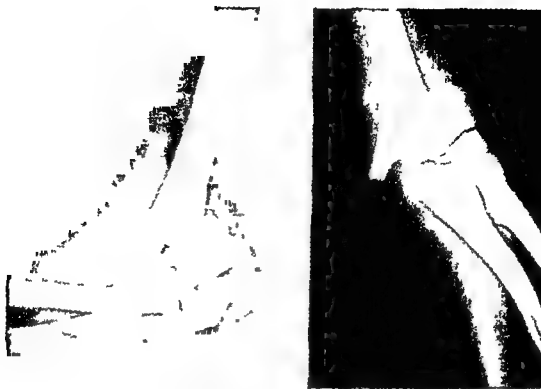


Figure 4a Pre-reduction X rays, lateral and a-p views



Figure 4b Example of excellent reduction, lateral and a-p views



Fig. 5 Post reduction fixation. Note the edge of adhesive plaster has been partially divided

Functional results

The results after the most recent follow-up examination were excellent in 45 patients (73.8 per cent), good in 11 (18 per cent) and poor in 4 (2 per cent).

Of the vascular complications seen on the first examination improved and no ischaemic fracture resulted.

The neurological complications recovered completely in one patient where a pointing index finger deformity persisted.

Five patients developed sepsis at the site of fracture of the skin by the lower end of the humeral fragment. Two of these patients developed osteitis at the fracture site.

Radiological results

At the time of the post-reduction X-ray examination, there were excellent radiological results in 40 patients (65.7 per cent), good in 19 (7 per cent) and poor in 9 (14.6 per cent).

Redisplacement occurred in five patients (8.2 per cent) on the fourth or fifth day after reduction but was not sufficiently severe to justify remanipulation.

The poor results

a) *Clinically* Two patients developed osteitis at the fracture site and ended up with an ankylosed elbow joint. In the three other patients, the fracture had been manipulated more than once previously. Varying degrees of cubitus varus were present. One of these patients showed also hyperextension of the elbow due to uncorrected posterior displacement of the distal fragment. In addition, one patient showed limitation of both flexion and extension of the elbow, the possible range of movement being 40°–110°. One other patient showed limitation of the last 30° of extension.

b) *Radiologically* Of the nine poor results encountered, four had had previous attempts at reduction. They presented grossly swollen elbows. In two more patients, the swelling was so severe that flexion of the elbow to greater than a right angle was not possible and redisplacement occurred. In the remaining three patients, reduction was unstable, although swelling was not marked and residual displacement had to be accepted.

DISCUSSION

In the treatment of any fracture, the objective is reduction into an anatomically acceptable and stable position without inflicting additional trauma. In addition the method of reduction recommended should if possible be easy to apply and should not require prolonged stay in hospital. In the treatment of supracondylar fracture of the humerus in children, closed manipulative reduction has been preferred to the other methods described in the literature. Skin traction (Dunlop 1939) is

often inconvenient to the patient. It may be difficult to apply in young children (Conwell & Reynolds 1961) and may result in distraction or over-riding with the resultant dangers (Staples 1959). Skeletal traction (Hart 1942) has the danger of infection of the pin tract, possible damage to the ulnar nerve (Wainwright 1962), and distraction at the fracture site (Staples & Hanover 1958). Open reduction may be complicated by infection and the incidence of joint stiffness is definitely higher than with other methods (Hammond 1952). In addition, these methods require a relatively longer stay in hospital than is necessary after closed manipulative reduction.

The technique of closed manipulative reduction described by other authors consists of traction on the injured limb from the wrist against counter-traction from the axilla (Blount 1955) with the elbow straight (Charnley 1968). Sharrard (1971) advised traction with the elbow slightly hyperextended. This however, proved to be unsafe as it was followed on occasions by rupture of the median nerve and injury to the brachial artery (Bristow 1923, Platt 1928) by the sharp edge of the distal end of the proximal fragment (Griffiths 1968). These disadvantages are obviated if manipulation is carried out with the elbow flexed 40° – 60° . This technique has other advantages also. Reduction of the posterior displacement is easier by this method as the posterior structures ("the posterior hinge") only are tightened. The tissues in front of the elbow remain lax and give way in front of the distal fragment whilst it is moulded forward by the tightening posterior hinge. It allows maximum traction to be effected at the site of the fracture without subjecting the neurovascular bundle to overstretching. Unlike manipulation in extension, during which the surgeon has to lean backward to effect maximum pull, he leans forward during manipulation in flexion. This enables him to maintain traction with one hand whilst manipulating the fracture with the other hand, thus the need for a second assistant is obviated.

Immobilization is carried out with a collar-

and-cuff or broad sling with the elbow Jones' position. In this way the forearm exposed for observation of the radial pulse is also more convenient than the methods described in the literature. Application of zinc oxide adhesive plaster about the elbow (Figure 5) and padding the limb under the child's clothing are particularly useful in difficult children. As slight placement occurred in only five patients (per cent), and did not require it is concluded that the method is as effective. Zinc oxide adhesive plaster applied must not encircle the limb completely and it is preferable to partially divide its edge to avoid cutting into the skin (Figure 6).

The use of the Jones' position has been blamed for inadequate assessment of restoration of the carrying angle. It is important to realize that the carrying angle is best restored and maintained by achieving accurate reduction. The impingement of the cortices of both fragments indicates maintenance of reduction, and hence the carrying angle. Restoration of the carrying angle is assessed with the elbow flexed when the re-alignment of the epicondyles with the epicondylar ridges and by the Smith method (Smith 1960). The Jones' position provides "the natural splint position" as the tightened posterior hinge moulds the condylar fragment in place and diminishes the possibility of redisplacement.

Conclusions

1) Manipulation of supracondylar fracture of the humerus by traction on the forearm with the elbow flexed 40° – 60° avoids stretching the neurovascular bundle across the distal end of the proximal fragment. It also facilitates reduction.

2) The carrying angle is best restored and maintained by achieving accurate reduction. With the elbow flexed, it can be judged by the re-alignment of the epicondyles with the epicondylar ridges and the visual method described by Smith (1960).

3) A collar-and-cuff with the elbow in

position provides an efficient and easy of fixation of the reduced supracondylar fracture

ACKNOWLEDGEMENT

If the illustrations contained in this article pleased with the kind permission of the Editor of the Orthopaedic Journal to whom the author ful

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COTREL TRACTION, EXERCISES, CASTING IN THE TREATMENT OF IDIOPATHIC SCOLIOSIS

A Pilot Study and Prospective Randomized Controlled Clinical Trial

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A pilot study of ten individuals with adolescent-onset idiopathic demonstrated that a week of Cotrel traction and exercises did not a curve correction obtained by the application of an elongation, flexion (EDF) cast. There was however, a significant improvement

Key words scoliosis traction, exercises casts, lateral bending

Accepted 1 x.77

The scoliosis treatment team in this centre was impressed by the management of scoliosis as demonstrated by Cotrel & Morel (1964) when they visited Berck Plage. Subsequently Cotrel visited Louisville and demonstrated his technique of traction, exercises, and casting (elongation, derotation, flexion-EDF). Since then we have used this method for the non-operative treatment of idiopathic scoliosis but have been disappointed with the long-term results. Furthermore it is time-consuming in terms of manpower and hospitalization.

Nachemson & Nordwall (1976, 1977) demonstrated that Cotrel traction is of no value in the preoperative phase of treatment of idiopathic scoliosis. Their patients did not achieve a better operative correction of their curve nor did any benefit in terms of safety accrue when surgery was preceded by a week of traction. Ramsay et al (1976) have shown

that with Cotrel traction curve correction be obtained but that no further improvement

"loosening-up" exercises, or indeed were responsible for curvature correction. A study and a prospective randomized controlled clinical trial were therefore carried out.

PILOT STUDY

Patients and method

Ten consecutive patients with adolescent idiopathic thoracic scoliosis were investigated. There were nine females and one male. Their age was 12.9 years. They underwent our outpatient treatment programme of traction and physical therapy exercises and were EDF casted the eighth day after admission. Traction was

f autologation and these individuals were aged to perform this throughout the day. At the traction was altered to fixed traction with 5 lb rising to 12 lb on their seventh physical therapy exercises were performed in the gymnasium for two 1-h periods each day under the supervision of a physical therapist. In addition 20 exercises were performed 15 times in succession and the various exercise routines treated on lateral bending correction of the trunk and pelvic tilting to mobilize the concomitant lordosis. On the eighth day an EDF cast was applied under maximum tolerable fixed traction. In order to control the investigation these individuals were similarly EDF casted on day 1 and treatment was commenced. This cast was moved in order that they could go through the treatment regime. Series of antero-posterior (AP) radiographs of the spine were taken during the treatment period and curves were measured by the Cobb method (1948). The variables studied were:

- 1. Standing curve before treatment
- 2. Curve on lateral bending before treatment
- 3. Standing curve in first cast, before treatment
- 4. Curve on lateral bending before second cast
- 5. Curve under maximum traction before second cast
- 6. Standing curve in second cast, after treatment

The mean magnitude of deformity during sitting before treatment was 43°, on lateral bending before treatment 20°, and standing in first cast 26°. Table 1 shows the effect of traction and exercises on the standing curve in the cast, and on lateral bending curve measurements in the casts on day 1 and day 8, 26° and 26° ($P > 0.05$). Lateral bending corrected the curve from 20° to 13°, a statistically significant correction at the 0.1 per cent level. In no case did the maximum correction equal or better the correction determined by initial lateral

bending, and cast correction was significantly worse than the maximum traction correction ($P < 0.05$).

Comment

From this pilot study it was considered that 8 days of hospitalization for traction and physical therapy was not justified if a policy of EDF casting was to be pursued, as no benefit in terms of curve correction in the cast occurred from such a treatment regime. However, it appeared that treatment had improved the lateral bending correction significantly and considerably. As the maximum traction correction after treatment did not even approach the initial lateral bending correction, physical therapy exercises seemed to be the most likely cause of the improvement in lateral bending correction. A prospective, randomized, controlled clinical trial was therefore carried out.

PROSPECTIVE, RANDOMIZED, CONTROLLED CLINICAL TRIAL

Patients and method

The next 20 patients with a diagnosis of adolescent onset idiopathic scoliosis were randomly allocated to one of two treatment groups:

1. Traction and no exercises
2. Exercises and no traction.

Traction or exercises were performed as in the pilot study.

The mean age of the two groups of patients did not differ significantly, 13.1 years and 13.6 years ($P > 0.05$) nor did mean curve magnitude before treatment, 42° and 40° ($P > 0.05$). The same variables were studied in these groups as in the original pilot study.

Results

1. Traction only Table 2 shows the effect of traction on the standing curve in the cast and the curve on lateral bending. There was no significant difference between the cast measurements on day 1 and day 8, 32° and 35°, respectively ($P > 0.05$). Nor was there any

Table 1 Results of pilot study

	1	2	P
Standing curve in cast	26°	26°	> 0.05
Curve on lateral bending	20°	13°	< 0.001

COTREL TRACTION, EXERCISES, CASTING IN THE TREATMENT OF IDIOPATHIC SCOLIOSIS

A Pilot Study and Prospective Randomized Controlled Clinical Trial

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A pilot study of ten individuals with adolescent-onset demonstrated that a week of Cotrel traction and exercises did not
clinical trial showed that the exercise programme and not the responsible for rendering the spine less rigid

Key words: scoliosis, traction, exercises, casts, lateral bending

Accepted 1.2.77

The scoliosis treatment team in this centre was impressed by the management of scoliosis as demonstrated by Cotrel & Morel (1964) when they visited Berck-Plage. Subsequently Cotrel visited Louisville and demonstrated his technique of traction, exercises, and casting (elongation, derotation, flexion-EDF). Since then we have used this method for the non-operative treatment of idiopathic scoliosis but have been disappointed with the long-term results. Furthermore it is time-consuming in terms of manpower and hospitalization.

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that with Cotrel traction curve correction be obtained but that no further improvement is achieved after 8 days. Physical therapy, integral part of this treatment programme, it is not clear whether the traction "loosening-up" exercises, or indeed both, are responsible for curvature correction. A study and a prospective randomized clinical trial were therefore carried out.

PILOT STUDY

Patients and method

Ten consecutive patients with adolescent idiopathic thoracic scoliosis were investigated. There were nine females and one male. Their age was 12.9 years. They underwent our non-operative patient treatment programme of traction, physical therapy exercises and were EDF casted the eighth day after admission. Traction was

SPONTANEOUS REGRESSION OF A MALIGNANT PRIMARY BONE TUMOUR

PER DISSING, JAN HEERFORDT, TORBEN SCHIÖDT
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Abstract. A 47-year-old man with a 10-year history of a malignant primary bone tumour of the iliac bone, which had been diagnosed as osteosarcoma, underwent a wide resection and reconstruction of the iliac bone. The tumour regressed spontaneously after the operation. The patient is now free of disease for 10 years. The histological findings of the regressed tumour were consistent with those of a chondroblastoma. The regression of the tumour was probably due to the removal of the tumour tissue during the operation.

up

Key words: osteosarcoma, chondroblastoma, bone tumour, spontaneous regression

Accepted 17 May 77

The literature contains very few reports of spontaneously regressed histologically confirmed malignant tumours. Considering that malignant primary bone tumours make up only 0.5 per cent of all malignant tumours, cases of spontaneous regression in this group of tumours are of course extremely rare. To our knowledge, only three are on record (Everson & Cole 1966).

CASE REPORT

A 47-year-old man was first seen in 1967 with a

swelling of the left thigh and a lump, physical examination showed no abnormalities. Radiography disclosed a widespread osteolytic lesion in the left half of the pelvis (Figure 1). Chest radio-

graphy was normal. ESR was 100 mm and alkaline phosphatase was slightly elevated. Open biopsy was done at the anterior demarcation of the tumour in the iliac bone. It showed — as did subsequent revisions of the same preparations — benign chondroblastoma (Figure 2a). In view of the clinical and radiological findings, however, this diagnosis did not seem convincing. Therefore, an exploratory operation through a wide posterior approach was performed in March 1971. In the iliac bone there was a tumour about 12 × 8 × 8 cm, anteriorly involving the superior ramus of the ischium and posteriorly the sacro-iliac joint and the lateral mass of the sacral bone. Ample tumour tissue was excised for histological examination which showed — as did subsequent histological revisions of these preparations — a malignant, primary bone tumour,

which had regressed after the operation.

After the operation the patient received only symptomatic treatment, viz., non-weight-bearing and analgesic medication.



Figure 1 Primary radiography, in January 1971, showed an osteolytic tumour involving the ramus of the ischium as well as the ilium, from the sacroiliac joint proximally to the acetabulum distally.

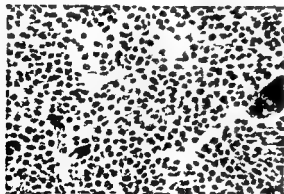


Figure 2a First biopsy Cellular tumour tissue with scattered giant cells suggestive of osteoclasts. The tumour cells are small and uniform, with distinct cell borders. Interpreted as a benign chondroblastoma. x350

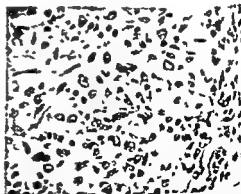


Figure 2b Second biopsy A more polymorphous appearance with more ample intercellular substance and pleomorphic giant cells. The tumour cells show variations in shape, size, and chromatin content of the nuclei. Cell borders indistinct. In places the intercellular substance shows the nature of osteoid. Interpreted as osteosarcoma or a malignant chondroblastoma. x350



Figure 3 Radiography in May 1972 revealed progression of the tumour with extensive destruction involving the sacrum and the majority of the acetabulum

Over the next few years the patient, still treated, was followed up in the outpatient clinic until the spring of 1973 his condition deteriorated rapidly. The regional pain grew worse and now he had rest pain. The left leg became 2 cm shorter and the difficulty in walking increased, necessitating the use of two English canes. Radiographic examinations during this period showed increasing destruction of the left half of the pelvis (Figure 3). But in the course of the latter half of 73

well. There have not at any time been signs of dissemination of the tumour, in particular not to the lungs.

DISCUSSION

Everson & Cole, in 1966, collected the cases of apparently spontaneous remission of histologically confirmed malignant tumours from the available literature. Among these tumours were eight primary bone tumours, including four osteosarcomas (one of these four cases has also been described by Levin in 1957). Everson & Cole themselves use the term cases of possible spontaneous regression.

clinical improvement a radiological remission took place. The tumour area became increasingly limited and sclerosed (Figure 4). When last seen in March 1977 the patient was feeling perfectly



Figure 4 In March 1977 the radiological remission is unmistakable. The tumour area is well-defined, increased sclerosis

implying that reports of an apparently spontaneous remission of a histologically confirmed malignant tumour should be regarded with scepticism and diagnostic criteria should be very strict.

In the present case the most recent clinical and radiological follow-up examination was performed 9 years after the onset of symptoms, 5 years after the biopsies, and 4 years after the time at which bony destruction was radiologically at a maximum. The second biopsy showed a primary bone tumour having definite malignant features (Figure 2b). Exact classification was less certain. It might be either a rare case of malignant chondroblastoma (McLaughlin et al 1975, Riddell et al 1973, Sirsat & Doctor 1970) or – more probably – a highly differentiated chondro-

blastic osteosarcoma. Thus, apparently a case of clinical and radiological, spontaneous remission of a bone tumour which has been classified as undoubtedly malignant according to both radiological and histological findings.

Stewart (1952) has discussed the various possible causes of spontaneous remission: hypersensitivity reactions, haemorrhage into the tumour, and a reaction to the tumour products. Immunological factors have been mentioned as a cause of spontaneous regression of many tumours. However, O'Hara et al. (1968) did not find any known specific immunological factors which could explain the long survival, in particular with osteosarcoma. They concluded that other host-tumour relationships must be operative in the defence mechanism. Woodruff (1969) has reported the appearance

comas in relation to immunosuppressive py. In the patient reported above we do not suggest any reason whatsoever for why regression took place.

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A PHOTOELASTIC STUDY OF A MODEL OF THE PROXIMAL FEMUR

A Biomechanical Study of Unstable Trochanteric Fractures I

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In an attempt to standardize an experimental model for biomechanical studies of unstable trochanteric fractures, acrylic models of the proximal femur were investigated by the photoelastic technique. By matching the stress distribution in the acrylic models to those calculated by Pauwels, it was found that the optimal femoral shaft and resultant hip joint forces were 5° and 6° to the vertical, respectively. The abductor muscle force was determined to be 55 per cent of the resultant hip joint force at 15° inclination to the vertical.

Key words: biomechanics, femoral neck, joint forces

Accepted 8 ix.77

Wolff (1870) described the architecture of the trabecular system in the femoral neck as being in accordance with the mathematical stress trajectories. A number of papers concerning the transmission of forces from the hip joint to the femoral shaft have confirmed his theories (Backman 1957, Inman 1947, Koch 1917, Tobin 1955, Williams & Svensson 1971) either through mathematical calculations or in laboratory investigations on cadaveric bone.

Pauwels (1935) introduced a simple mathematical analysis of the force vectors around the hip joint in order to calculate the load on the femoral head. Several more recent papers have discussed the magnitude and direction of the hip joint force and the abductor muscle force as well as the inclination angle of the femoral shaft. Somewhat conflicting results have been stated, however, concerning the relationships between these variables.

The aim of the present studies is to investigate the mechanical behaviour of different nail-plates in osteosynthesis of unstable trochanteric fractures. For this purpose, however, a standardized experimental model is needed as regards the inclination angles of the femoral shaft, the hip joint force and the abductor muscle force, as well as the relation between the magnitudes of the forces. To simplify the static experiments, these variables will be considered in the frontal plane only.

The photoelastic technique (Föppl & Schreyer 1972) has been widely used by engineers for the stress analysis of constructions which are difficult to describe in mathematical terms. Breckner & Albrecht (1972) mentioned this method as being useful in determining the mechanical behaviour of bone, although the anisotropic nature of bone was not taken into account. The photoelastic technique has been applied to

els (Fessler 1957, Milch 1940, Ruszkowski 1972) showing stress patterns corresponding with the stress trajectories in the proximal neck (Wolff 1870, Koch 1917, Pauwels 1973)

The present paper will present the results of the photoelastic technique applied in two-dimensional models of the proximal femur to a standardized experimental model with reference to the parameters mentioned

MATERIALS AND METHODS

Photoelasticity (Foppl & Monch 1972) is based on the fact that some transparent, isotropic solids become birefringent under mechanical load. For experimental purposes an exact model of the proximal femur is made from a photoelastic material (Araldite-B[®]). The model is loaded and illuminated with polarized light in a polariscope. The difference between the principal stresses at

any point in the model is proportional to the relative retardation of the two component rays of polarized light that pass through the point. When the relative retardations are equal to an integral multiple of the wavelengths of the light used, no light is transmitted. In monochromatic polarized light the lines of constant shear stress appear as black bands — the isochromates. In white polarized light the neutral axis, which is stress free, is seen as a dark band, while the isochromates appear in the colours of the spectrum. The isochromates are numbered (i.e. ordered) from the neutral axis which is called the zero-isochromate. The number of isochromates thus increases with increasing mechanical stress.

Based on measurements made on X-rays of normal hip joints from five patients, two-dimensional models of the proximal femur were manufactured in polyester (Araldite-B[®]). An idealized model with a femoral neck angle of 130° and one of 140° were made.

The model was fastened to a steel socket and placed in the polariscope (Tiedemann A 159, W. Germany). The model was loaded vertically (Figure 1) by a steel bar (weight = 6.8 Newton) supplemented with a load proving ring (Tiedemann H 256 M, W. Germany) weighing 3.2 N, on which a screw press was applied — the total load being

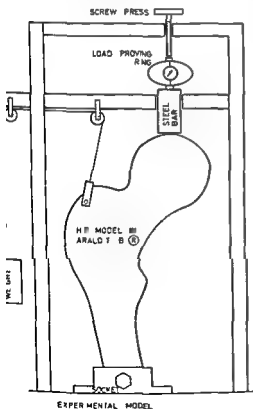


Figure 1 Experimental arrangement

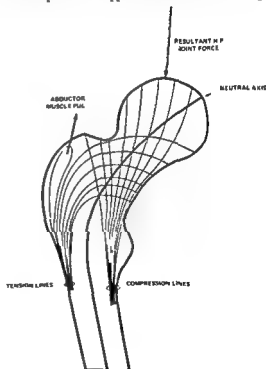


Figure 2 Reconstruction of stress trajectories (Koch 1917, Pauwels 1973)

These figures represent average values of papers referred to in the discussion.

the greater trochanter of the model. The model was viewed in polarized light and the picture on the analyzer screen was photographed and compared with the stress trajectories (Figure 2) reconstructed from Koch (1917) and Pauwels (1935-1973).

The force vectors and the inclination angles are shown in Figure 3.

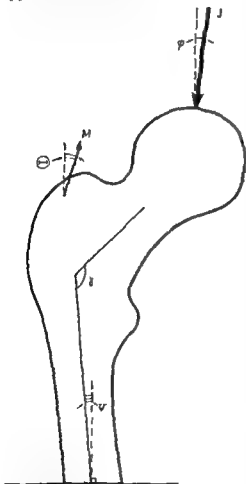
In the experimental series the parameters were varied as follows, although corrections were made according to the vertical loading of the models

ψ = femoral shaft inclination $5^\circ, 10^\circ, 15^\circ$

φ = hip joint force inclination $6^\circ, 11^\circ, 16^\circ$

Θ = abductor pull direction $10^\circ, 15^\circ, 20^\circ$

$\frac{M}{J}$ = abductor muscle force / hip joint force 0.55, 0.60, 0.65



FORCES AT THE PROXIMAL FEMUR

J = RESULTANT HIP JOINT FORCE
M = ABDUCTOR MUSCLE FORCE
 ψ = FEMORAL NECK ANGLE
DOTTED LINES INDICATE VERTICAL

φ = JOINT FORCE INCLINATION
 Θ = ABDUCTOR PULL INCLINATION
 ψ = FEMORAL SHAFT INCLINATION

RESULTS

Sixty-five experiments were performed on the 140° femoral neck model and 130° neck angle. Examination of the results from the experiments on both models showed that the optimal arrangement with the parameters mentioned consisted of a femoral shaft inclination (ψ) of 6° and an abductor pull inclination of 15° . The magnitude of the abductor force (M) was determined to be 55% of the resultant hip joint force (J). These values were chosen as the stress patterns in Figure 4 and Figure 5 corresponded with the stress trajectories shown in Figure 2. Stress patterns not corresponding to the stress trajectories were rejected, as demonstrated in Figure 6 ($\psi = 15^\circ$, $\varphi = 11^\circ$, $\Theta = 15^\circ$, $M/J = 0.55$).

In this series of experiments the effect of an increased femoral shaft inclination and an increased joint force inclination were similar. Both displaced the neutral axis laterally (Figure 6) and with increased inclination of the model, the stress pattern changed from compression to tension on the medial part of the neck and shaft (Figure 7).

The direction (Θ) and magnitude of the abductor muscle pull in relation to the resultant hip joint force (M/J) did not show any great effect on the stress patterns in the model. In this series of experiments Θ was determined as 15° and M/J as 0.55. Altering the abductor pull direction to 10° or 20° displaced the neutral axis slightly laterally and $\Theta = 20^\circ$ involved a slight increase in the number of isochromates in the medial part of the shaft. Increasing the abductor muscle force in relation to the resultant hip joint force increased the bending moment and displaced the neutral axis slightly in the lateral direction.

Figure 3 Forces at the proximal femur

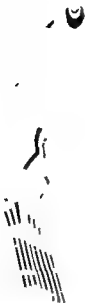


Figure 4 Normal hip model 130° femoral neck angle
 $\psi=5^\circ, \varphi=6^\circ, \Theta=15^\circ, M/J=0.55$



Figure 5 Normal hip model 140° femoral neck angle
 $\psi=5^\circ, \varphi=6^\circ, \Theta=15^\circ, M/J=0.55$

DISCUSSION

Two-dimensional studies of hip models have been carried out using the photoelastic technique (Haboush 1952, Milch 1940, Fessler 1957, Ruszkowski & Muftic 1972). The method has been considered useful in experimental research by Brekelmans et al (1972). A three-dimensional photoelastic technique was introduced by Hetenyi (1939) and has also been applied to hip models (Fessler 1957, Williams & Svensson 1971). This technique is however much more complex and has not contributed an increase in information (corresponding with the complexity) as compared with the rather simple two-dimensional technique, both methods revealed stress patterns corresponding to Hoff's trajectories (Fessler 1957, Milch 1940, Ruszkowski & Muftic 1972). In the present study it has been the author's

aim to consider the force vectors and the femoral shaft inclination in a two-dimensional static study in the frontal plane, as this is the most practical arrangement for further laboratory investigations. It is obvious that the results obtained can not directly be used clinically as the eccentric position of the centre of gravity, the muscle pull from the thigh muscles, the forces of the ligaments and the anteversion of the femoral neck were not considered. The shear stresses are higher in the central plane in the model than average because of the isotropy of the model material. In the experiments the influences of deformations of the model and probable shear forces from torque were not taken into account, but were assumed not to alter the stress patterns.

Accepting the obvious limitations of the technique and the experimental arrangement, the author has found it worthwhile to determine an optimal model with reference to

equivalent to the resultant hip joint force (J) The abductor muscle pull was applied by weights ($=70$ N) over a system of pulleys to a hole drilled in the greater trochanter of the model The model was viewed in polarized light and the picture on the analyzer screen was photographed and compared to the stress trajectories (Figure 2) reconstructed from Koch (1917) and Pauwels (1935, 1973)

The force vectors and the inclination angles are shown in Figure 3

In the experimental series the parameters were varied as follows, although corrections were made according to the vertical loading of the models

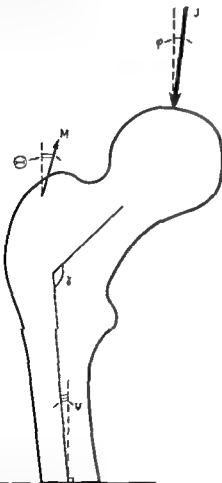
ψ = femoral shaft inclination $5^\circ, 10^\circ, 15^\circ$

φ = hip joint force inclination $6^\circ, 11^\circ, 16^\circ$

Θ = abductor pull direction $10^\circ, 15^\circ, 20^\circ$

$\frac{M}{J}$ = abductor muscle force / hip joint force 0.55, 0.60, 0.65

J = hip joint force



FORCES AT THE PROXIMAL FEMUR

J RESULTANT HIP JOINT FORCE ψ JOINT FORCE INCLINATION
M ABDUCTOR MUSCLE FORCE Θ ABDUCTOR PULL INCLINATION
F FEMORAL NECK ANGLE φ HIP JOINT FORCE INCLINATION
DOTTED LINES INDICATE VERTICAL

Figure 3 Forces at the proximal femur

These figures represent average values from papers referred to in the discussion

RESULTS

Sixty-five experiments were performed on the 140° femoral neck model: experiments on the model with a 1° neck angle. Examination of the results from the experiments on both models showed that the optimal arrangement with the parameters mentioned consisted of a femoral shaft inclination (ψ) of 15° in combination with a joint force of 6° and an abductor pull inclination of 15° . The magnitude of the force (M) was determined to be 55% of the resultant hip joint force (J). These were chosen as the stress patterns in Figure 4 and Figure 5 correspond with the stress trajectories shown in Figure 2. Stress patterns not corresponding to the stress trajectories were rejected, as demonstrated in Figure 6 ($\psi=15^\circ$, $\varphi=11^\circ$, $\Theta=15^\circ$, $M/J=0.55$).

In this series of experiments the effect of an increased femoral shaft inclination and an increased joint force inclination were similar. Both displaced the neutral axis laterally (Figure 6) and with an increased inclination of the model, the stress pattern changed from compression to tension on the medial part of the neck and shaft (Figure 7).

The direction (Θ) and magnitude of the abductor muscle pull in relation to the resultant hip joint force (M/J) did not show any great effect on the stress patterns in the model. In this series of experiments Θ was determined as 15° and $M/J=0.55$. Altering the abductor pull direction to 10° or 20° displaced the neutral axis slightly laterally and $\Theta=20^\circ$ involved a slight increase in the number of isochromates in the medial part of the shaft. Increasing the abductor muscle force in relation to the resultant hip joint force increased the bending moment and displaced the neutral axis slightly in the lateral direction.

gnitude of the abductor muscle pull was determined to be 55 per cent of the resultant joint force in accordance with the results of other studies (McLeish & Charnley 1970, Pauwels 1935, Rydell 1966, Williams & Svensson 1968). In conclusion, the author considers the standard experimental method described, as found through photoelastic studies, to be acceptable and very useful for further laboratory investigations of the unstable trochanteric fracture.

ACKNOWLEDGMENTS

Gratitude is expressed to Erik Gløbe, M.Sc.Eng., Copenhagen Engineering College, for invaluable help. The study was kindly supported by the Danish Medical Research Council, Grant No 12-6595.

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Figure 6 Rejected stress patterns

$\psi = 15^\circ$, $\varphi = 11^\circ$, $\Theta = 20^\circ$, $M/J = 0.55$

Stress patterns not in accordance with Wolff's trajectories. Neutral axis displaced laterally. The isochromates are tension lines in the medial part of the shaft. There is practically no bending in the neck.



Figure 7 Rejected stress patterns

$\psi = 15^\circ$, $\varphi = 16^\circ$, $\Theta = 15^\circ$, $M/J = 0.60$

Neutral axis is the most laterally situated. The isochromates in the medial part of the neck and shaft are all tension lines demonstrating a bending moment.

the aforementioned parameters, as variations of these showed considerable changes in the stress trajectories (Koch 1917, Pauwels 1935, 1973, Wolff 1870). During the past 40 years many attempts have been made to determine the force vectors around the hip joint and somewhat conflicting values have been reported for the femoral shaft inclination (ψ), the resultant hip joint force (J) and its inclination (φ) and the abductor muscle pull (M) and its acting direction (Θ), as well as the relations between the magnitudes of the two forces.

Prior to the present study, calculations were made from values stated in previous papers considering all these variables in studies of the static one-legged stance. Calculated values of

M/J varied from 0.40–0.60 (McLeish & Charnley 1970, Pauwels 1935, Rydell & Williams & Svensson 1968) to 0.65 (Arntmann & Kummer 1968, Denham & Hamacher & Roesler 1972, Loman 1947). In the same studies the joint force inclination has been reported as being between 6° and 17° and the abductor pull direction between 10° and 21° , while the femoral shaft inclination (ψ) has been stated as being between 5° and 15° .

In this series the femoral shaft inclination was determined to be 5° in accordance with Pauwels (1935). The joint force inclination was found to be 6° and the direction of the abductor muscle pull to be 15° , which agrees well with McLeish & Charnley (1970).

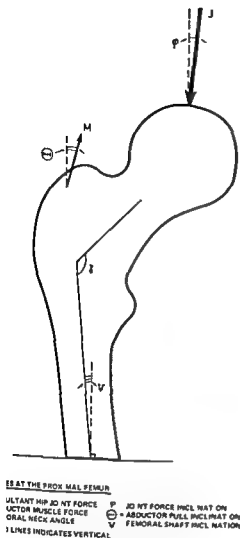


Table 1 Order of isochromates according to nail plate angle

Nail plate angle	Order in nail	Order in plate
125°	50	65
135°	45	55
140°	40	50
150°	35	45
160°	30	35

The values stated are average values.
The order in the nail is counted 3 cm proximal to the connection between nail and plate and the order in the plate 3 cm distal to the connection.

vertical to clarify the influence of the femoral shaft inclination ($\psi=5^\circ$) and the inclination of the hip joint force ($\varphi=6^\circ$)

The osteosynthesis models of the unstable trochanteric fracture were loaded at 11° inclination, with the hip joint force amounting to 15.0 Newton. In order to clarify the influence of the abductor muscle force this was applied with 15° inclination and amounted to 55 per cent of the hip joint force (= 8.25 Newton).

RESULTS

Twenty experiments were performed with the nail-plate models and 47 experiments with the osteosynthesis models of the unstable trochanteric fracture without medial support.

Table 1 demonstrates that an increase of the angle between the nail and the plate significantly reduced the order of isochromates ($P < 0.0005$, Kruskal-Wallis test).

The maximum shear force (τ_{max}) in the model of the nail can be expressed by the equation (Foppl & Monch 1972)

$$(1) \tau_{max} = \frac{S}{0.2 \times d} \times \delta$$

(S = photoelastic constant, which for Araldite- B^* = 10 N/mm^2 , d = thickness of model = 10 mm , δ = order of the isochromates). For the current experiments the equation will thus be

$$(2) \tau_{max} = 0.5 \times \delta \text{ N/mm}^2$$

The order of isochromates in the distal part of the nail of a 125° nail plate (Figure 2) was

1 Forces at the proximal femur

description given in the previous paper (Jensen 1980). This included loading of the model in a scope with simultaneous application of motor muscle force. The femoral shaft inclination (ψ) was 5° , the joint force inclination α , the abductor pull direction (θ) 15° and the angle of the abductor pull (γ) was 55 per cent of joint force (J) (Figure 1). Lines of constant stress in the nail-plate, the isochromates, were derived from the centrally placed neutral axis at 3 cm of the nail and the proximal 3 cm of the bone before the connection to give the order of isochromates.

models of the nail-plates were loaded in the vertical position and at 11° inclination to the



Figure 2 Stress patterns in a 125° nail-plate. The thin interrupted centerline is the neutral axis (=zero-isochromate). The isochromates are numbered from the neutral axis. In the distal part of the nail near to the connection with the plate five isochromates can be counted.

Figure 3 Stress patterns in a 150° nail-plate. The distal part of the nail near the connection with the plate 3.5 isochromates can be counted on each side of the centrally placed neutral axis.

found to be 5.0 (Table 1). The maximum shear stress is thus calculated as

$$\tau_{\max 125^\circ} = 0.5 \times 5.0 = 2.5 \text{ N/mm}^2$$

For a 150° nail-plate (Figure 3) the order of isochromates was 3.5 (Table 1) and the maximum shear stress is calculated as

$$\tau_{\max 150^\circ} = 0.5 \times 3.5 = 1.75 \text{ N/mm}^2$$

The reduction in shear stress is thus about 30 per cent by using the 150° nail-plate as compared with the 125° nail-plate. As seen from Table 1 the order of isochromates and thereby the maximum shear stress is even

considerably larger in this area. Experiments on the osteosynthesis model demonstrated that the abductor muscle increased the shear forces. The order of isochromates was 0.5–1.0 higher when the abductor pull was applied to the model compared to the situation where the pull force was acting separately.

The experiments on the nail-plate model demonstrated that loading the model with an inclination of 11° to the vertical, corresponding to a femoral shaft inclination of 6° and a joint force inclination of 6°, reduced the order of isochromates by 0.5–1.5 in the distal part of the nail and by 1.0–2.0 in the proximal part of the plate as compared with the experiment with the plate positioned vertically.

DISCUSSION

biomechanical experiments on medial neck fractures (Haboush 1952, 1953, Fry et al. 1959, Spoftoft 1949) it is known that a steeper placement of the nail reduces the load on the nail and thereby increases the mechanical strength of the osteosynthesis. Melander (1963), however, pointed out the importance of considering also the trabecular structure and the mechanical properties of the

bone. In the unstable trochanteric fracture without medial support the nail-plate alone must transmit the entire load from the femoral head to the femoral shaft. Sarmiento (1963) recommended a steep placement of the nail for trochanteric fractures to reduce the mechanical load on the implant. Some authors (Sarmiento 1958, Grover 1966, Martz 1956) have reasoned that the connection between the nail and the plate was the weak point in the construction and thus the most susceptible to mechanical failure.

The photoelastic technique used in this study has its obvious limitations (Jensen 1963). The stress patterns are for instance only considered in the frontal plane, and deformation of the model is assumed not to influence the stress patterns. The model is considered free from sagittal forces.

Despite the rather simple mathematical calculations given in this paper the maximum shear stress in the distal part of the nail of a 125° nail-plate was found to be 2.5 N/mm². In the model was loaded with 150 N. In comparison, the maximum shear force in the nail of a 150° nail-plate was calculated as 1.75 N/mm². From Paul's studies (1967) it is known that the human hip joint is exposed to forces of about six times the body weight in normal level walking.

A rather simple calculation can be made from the experimental values to estimate the shear forces on the Jewett nail for each step. A woman of 60 kg (≈589 N) takes during walking. The maximum shear stress in a 125° nail-plate would thus be calculated to be $1/150 \times 589 \times 11 = 589 \text{ N/mm}^2$. In a similar

situation applying a 150° nail-plate the maximum shear stress amounts to $1.75/150 \times 589 \times 6 = 412 \text{ N/mm}^2$, which is only 70 per cent of the stress on the 125° nail-plate. As the hip is exposed to cyclic loading during walking the implant has to absorb a considerable amount of energy during the time of fracture union. The risk of implant failure due to metal fatigue increases with increased shear force.

In this series only the stress patterns in the implant have been considered. The mechanical behaviour of the surrounding bone with its osteoporosis and reduced mechanical strength has not been taken into account and neither has the geometry of the bone-nail interface. Further laboratory investigations will therefore be undertaken on cadaveric bone to clarify the mechanical behaviour of the unstable trochanteric fracture without medial support.

From this series of experiments it can be concluded that in osteosynthesis of unstable trochanteric fractures a steep placement of the nail plate is to be recommended from purely mechanical considerations.

ACKNOWLEDGEMENTS

Gratitude is expressed to Erik Glube, M.Sc. Eng., Copenhagen Engineering College for invaluable help. The study was kindly supported by the Danish Medical Research Council, Grant No. 512-6595.

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PERFORATION OF THE URINARY BLADDER AND SMALL INTESTINE CAUSED BY A TROCHANTERIC PLATE

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A case is presented of a pertrochanteric plate which penetrated into the pelvis causing perforation of the urinary bladder and small intestine

Key words: intestinal perforation, orthopaedic fixation devices, postoperative complications

Accepted 21 viii.77

Trochanteric fractures are common in the elderly. The frequency of complications after internal fixation of unstable pertrochanteric fractures is about 25 per cent (Laros & Moore 1974). A common complication is penetration of the nail through the femoral head into the acetabulum and sometimes even into the pelvis as in the case presented below.

CASE REPORT

A 78-year-old female was admitted to our hospital because of a fresh pertrochanteric fracture of the femur.

Three days after the trauma the fracture was fixed with an ASIF 130° blade plate and a lag screw (Figure 1). The postoperative course was uneventful. The patient returned to the nursing home and was able to walk with support. Two months after the operation an X-ray examination revealed penetration of the plate through the femoral head and acetabulum into the pelvis (Figure 2). Since the patient was able to walk without pain reoperation was not considered necessary.

Eight months after the operation the patient was again admitted to hospital because of acute abdominal pain. X-ray examination showed dilated intestinal loops and several fluid levels. There was no free gas in the peritoneal cavity. The radiological and clinical findings were typical of an ileus (Figure 3). An operation was performed

on the same day. The ASIF plate was found to have penetrated 5 cm inside the pelvis. Three perforations were seen in the ileum and two perforations in the urinary bladder. The plate was removed, the ileum resected, and the perforations in the urinary bladder were sutured. The patient made a good recovery after the operation.

DISCUSSION

Fractures without medial support in the calcar region are considered unstable (Evans 1949, Steen Jensen & Michaelson 1975) with risk of fracture displacement into a varus position (Dimon & Hughston 1967). As a result, the nail used for internal fixation may penetrate through the head into the acetabulum. A complication of this type is most likely to occur in elderly patients with severe osteoporosis (Laros & Moore 1974) and in cases of unstable fractures.

The fracture presented above was unstable and the bone was osteoporotic. Furthermore the reduction was unsatisfactory and the patient walked without support. As a result of this the fracture collapsed and the femoral shaft segment migrated medially and proximally. The nail penetrated the hip joint and the pelvis and subsequently perforated



Figure 1 Comminuted pertrochanteric fracture fixed with an ASIF blade plate and a screw.



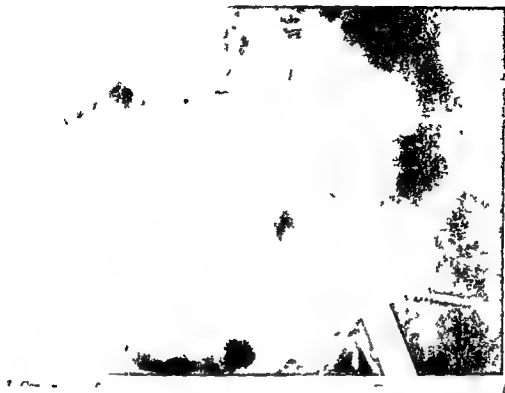
Figure 2 Two months after the operation blade plate has migrated through the femur and acetabulum into the pelvis

both the urinary bladder and the small intestine

From our experience of the ASIF system, we consider the condylar plate to be preferable to the standard 130° blade plate for fixation of unstable pertrochanteric fractures. The condylar plate gives a better possibility of fixing the fragmented calcar region to support the medial cortex and there is less risk of the nail penetrating into the acetabulum

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A ROENTGEN STEREOPHOTOGRAMMETRIC INVESTIGATION OF INNOMINATE OSTEOTOMY (SALTER)

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The effect of the osteotomy on the acetabulum

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and 24° laterally about a sagittal axis. The acetabulum

The correction as measured with the CE-angle was 25° which the same as the correction about the sagittal axis. It is, however, the CE-angle was also dependent upon the rotations longitudinal axes.

Key words: hip, osteotomy, pelvis, roentgen stereophotogrammetry, rhino-phalangeal syndrome

Accepted 19 ix.77

The principle of innominate osteotomy according to Salter is the redirection of the entire acetabulum in order to increase the joint stability and the contact surfaces between the femoral head and acetabulum (Salter 1961, 1969, Salter & Dubos 1974). The primary indication for this osteotomy is congenital dislocation of the hip with acetabular dysplasia but the method has been used for paralytic hip dislocation, Perthes' disease and certain types of fixed pelvic obliquity (Salter & Dubos 1974) and in acetabular dysplasia with osteoarthritis (Wedge & Salter 1974).

The degree of correction of the acetabulum has generally been estimated by determination of the CE-angle (Wiberg 1939) and has been

correlated with the clinical (Crellin 1974, Denton & Ryder 1974, Dubos 1974, Wedge & Salter 1974). In the innominate osteotomy Salter the acetabulum moves about identical with a sagittal axis. The of the acetabulum in the A., therefore different pre- and causing difficulties locating the same the determination of the CE-angle. To better information about this translation and rotation of the been determined by a roentgen grammetric method (Selvik 1974) tantalum indicators above and below osteotomy level.

CASE REPORT

The patient was a 17-year-old girl of short stature with a radiological right-sided acetabular dysplasia (CE-angle -3°) including deformation of the femoral head and neck with various positions (Figure 1). Roentgenological investigation showed several dysplastic deformations as in the trichophalangeal (Giedion) syndrome. During the previous 2 years there had been increasing disability in the right hip. Clinical examination showed normal movements in the hip but positive Trendelenburg's test. As operative procedure an innominate osteotomy on the right side according to Salter was chosen.

Operation

The operative procedure was performed according to the instructions for the operation of dislocated hips with acetabular dysplasia after 1961 (Olsson et al. 1976).



Figure 1 AP radiograph of the pelvis showing the dysplastic right hip

possible to open up the osteotomy enough to place and fix the triangular bone graft. The base was chosen according to Salter (1969) as the distance between the superior and inferior anterior iliac spines and measured about 3 cm. The length was estimated to be 5 cm resulting in an angular correction of about 30° with an anteriorly open angle.

After 6 weeks in a plaster spica the patient was mobilised. One year after the operation she has no complaints regarding her right hip and she has started to work again. Clinically there is now a negative Trendelenburg's test and the range of movement is almost normal. Postoperatively the right side is about 1 cm longer than the left side.

Roentgen stereophotogrammetric method

The primary objective of roentgen stereophotogrammetry is to determine the three-dimensional coordinates of structures in the body (Selvik 1974, Olsson 1975, Olsson et al. 1976). Generally, there are no sufficiently distinct points in the body to allow identification with high accuracy in the two projections necessary for a three-dimensional reconstruction. Thus, radiopaque indicators, tantalum balls with a diameter of 0.8 mm, were introduced in each skeletal segment studied. Following the technique of Aronson et al. (1974), an indicator was placed in the tip of a needle and deposited during fluoroscopy in the bone into which the needle had been forced 1–2 mm. These tantalum markers serve as measurement points on the radiographs. To allow for a study in terms of three-dimensional rigid-body motion, three indicators were placed in the ilium and three in the segment caudally to the osteotomy.

Simultaneous exposures of the pelvis with two roentgen tubes on one film were made pre- and postoperatively. On each film, a calibration cage supplied with tantalum indicators, the mutual positions of which are known, was also double-exposed. The coordinates of the images of both patient and calibration indicators were then measured by means of an instrument for cartography. The information thus obtained was treated by means of a computer so that the three-dimensional positions of the indicators were determined in a laboratory coordinate system. This laboratory coordinate system is defined by the calibration cage markers, which are situated in two planes. The patient is investigated in such a position that the main axes of the body (transverse, longitudinal and sagittal axis) are parallel to those of the cage coordinate system (Olsson et al. 1976). Identical orientation of the patient in different examinations is not necessary.

In the subsequent analysis, the rigid-body

motion between the indicated segments was computed and the results were visualized by computer drawings and on radiographs. The iliac indicators were taken as a reference. The rotations and translations of the caudal acetabular segment in relation to the ilium were given in the coordinate system of the preoperative investigation. In this analysis the reference segment in later investigations is calculated back to its position at the reference examination which explains why identical orientation on different occasions is not needed.

Besides the rotation angles about the main axes the total rotation and the position of an axis called the screw axis of the movement were calculated. The screw axis is the axis of rotation for a general rigid body displacement which is the closest approximation to the uniquely defined axis of rotation in a pure rotatory movement. Using the screw axis description the rigid body motion is a rotation about and a translation along the same axis. The position of the screw axis was related to frontal, lateral and axial orthographic projections of the indicators drawn by computer. To visualize it better it also was drawn on frontal and lateral radiographs exposed with the central ray passing through the midpoint of the indicators in the caudal segment. The position of the axis was

related to this midpoint but no correction was made for the radiograph being a central projection.

In contrast to the rotation angles, the translation varies over a segment if the motion is not a pure translation. As illustration the translation is given for a point in the roof of the acetabulum where one of the indicators was placed (Figs 2 and 3).

The precision of the method was earlier estimated to be approximately 0.2° for the rotations and 0.1 mm for the translations along the coordinate axes (Olsson 1975). In the two roentgen films were exposed at postoperative investigations. Comparing rotation angles and translations obtained

positions differed 0.1 mm

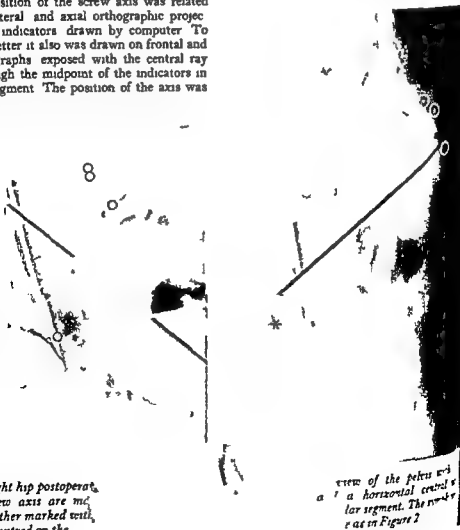


Figure 2 Right hip postoperative and the screw axis are marked. Indicator further marked with radiograph centred on the

view of the pelvis with a horizontal central ray of the acetabular segment. The results are as in Figure 2

RESULTS

The acetabulum rotated 22.3° forwards about a transverse axis (the cranial part moved forwards), 9.3° laterally about a longitudinal axis (the ventral part moved towards the right side of the patient) and 23.6° laterally about a sagittal axis (the cranial part moved towards the right) in relation to the right ilium. These

can also be expressed as a total rotation of 32.4° about the screw axis (Figures 2 and 3). It is found that this axis passes from the right, dorsal and cranial part of the pelvis to the left, ventral and caudal part, and it is noted that it passes cranially to the symphysis and cranially to the pubic symphysis.

The indicator in the acetabulum (Figures 2 and 3) was translated 1.6 mm towards the side of the patient along a transverse axis, 20.5 mm caudally along a longitudinal axis and 18.9 mm dorsally along a sagittal axis in relation to the right ilium. The translation along the screw axis was 4.8 mm in the forward direction.

DISCUSSION

The motion of the segment caudally to the osteotomy, including the acetabulum, was calculated in relation to the segment cranially to the osteotomy, but it was not known which segments was moving or if they both moved in opposite directions. If only the acetabulum had moved and the rest of the pelvis had constituted a rigid body the acetabulum should have rotated about an axis which passed through the pubic symphysis. As this was not the case (Figure 2) it is concluded that some motion also took place in one or both of the sacroiliac joints. This is indirect evidence that not only did the acetabulum move downwards, but that the ilium also moved upwards. This fact must be kept in mind when the operation is planned so it can be compensated for.

Concerning the size of the triangular bone graft, Salter (1969) has found that the length

of the base is no problem as the distance between the superior and inferior anterior iliac spines increases with age and compensates for the increased demand in size. However, as small children have relatively greater joint instability it can be anticipated that the ilium probably also moves relatively more in relation to the transverse plane in younger than in older children. Thus the gained tilt of the acetabulum will be relatively less in younger children.

In this case the CE-angle was changed from -3° to 22° by the osteotomy, indicating a better covering by the acetabulum which has also been found in previous investigations (Crellin 1974, Denton & Ryder 1974, Salter & Dubos 1974, Wedge & Salter 1974). As mentioned above, the calculation of the CE-angle is difficult. However, the noted change is about 25° , which is the same as the rotation about the sagittal axis (24°). There is also a considerable rotation about the transverse axis (22°), which contributes to a better covering of the femoral head. The rotation of 9° laterally about the longitudinal axis will therefore, in this particular case, not affect the height of the acetabular edge seen in the AP-projection.

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QUADRICEPS FUNCTION FOLLOWING INDIRECT NAILING OF FEMORAL SHAFT FRACTURES

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A series of 24 adult patients with isolated, unilateral fractures of the femoral shaft treated by indirect Street Hansen nailing is submitted. Follow up included clinical and radiological assessment as well as measurement of quadriceps strength as well as dynamic and range were

nailing

Key words quadriceps, function tests, strength fracture of femoral shaft, sequelae

Accepted 13.1.77

• most important requirements in modern treatment of fractures are the achievement of an as well as normal physical and social situation in the shortest possible span of time with the least possible risk to the individual patient (Charnley 1963). But as this involves several factors, the question of priority arises - and thus variations in the mode of treatment as well as in the assessment of the therapeutic results.

In the Odense University Hospital the routine treatment of fractures of the femoral shaft has been for several years traction in children and intramedullary nailing by a passive, rhombic Street-Hansen nail in adults.

Up to 1969 the operation involved open reduction with retrograde introduction of the nail. Since that time the routine surgical procedure has been closed reduction, introducing the intramedullary nail from the greater trochanter to the femoral condyle under transillumination. As an additional

parameter in the assessment of the therapeutic results, we have introduced measurement of the strength of the thigh muscles.

In 1972 the present authors submitted the therapeutic results of fractures of the femoral shaft in adults and in 1974 those in children, with special attention to muscle function (Damholt & Zdravkovic 1972, Damholt & Zdravkovic 1974).

PATIENTS

In this paper we are submitting the results of treatment of unilateral fractures of the femoral shaft in adults, having no other injuries, by closed reduction and indirect nailing by the Street-Hansen method.

The material comprises 24 patients, 6 females and 18 males in the age range 16-66 years, mean age 23 years. The follow-up period ranged from 2-6 years, mean 2.7 years.

Table 1 gives the situation in which the accidents occurred. The majority of patients had

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Table 3 Results of measurement of strength

	%	Isometric strength No of patients	Dynamic endurance No of patients
A > U	≥ 20.1	1	1
	20.0-10.1	1	1
	10.0-0.1	4	2
A = U	0	4	3
A < U	0.1-10.0	4	7
	10.1-20.0	4	3
	≥ 20.1	6	5

A = affected leg, U = unaffected leg

The measurements of strength were calculated according to the formula $U - A$ in per cent of U

Calculation formula of isometric strength and dynamic endurance worked out in collaboration with Sv. Molbech, M.Sc., of the Poho Institute Hellerup/Copenhagen (1971) (Formula obtainable on request from the authors.)

Table 4 Results of strength and endurance measurements in patients under and over 25 years of age. Figures in brackets indicate number of patients

	Percentage decrease of strength in affected leg	
	Isometric	Dynamic
Patients under 25 years (18)	6.5	7.5
Patients over 25 years (6)	22.8	33.3

ference showed no difference or a loss of less than 2 cm.

Results of measuring strength were compared with the measurements of force. For isometric strength the correlation coefficient was $r=0.39$ and for dynamic endurance $r=0.49$. Thus, the corresponding determination coefficients r^2 were 0.24, respectively. In other words, a change in one parameter can explain only 15 per cent and 24 per cent, respectively, of the change in the other.

In the follow-up 22 of the 24 patients were employed in the same or heavier work than before the accident. Two patients were not employed: one was out of work and one was attending school.

Prior to the accident 10 of the patients had been involved in competitive sport. Of them 6 went back to the same sport. Comparison of patients involved in sport and those who were not showed no statistically significant difference in the results of strength measurements.

Table 4 gives the mean decrease in isometric strength and dynamic endurance in the affected leg in per cent of the unaffected one — for patients under and over 25 years of age. There is a clear tendency towards a more marked decrease of strength in the older patients, but owing to the small number involved the difference is not statistically significant at the 5 per cent level. Two patients with rotation deformity showed a decrease of 24 per cent and 43 per cent in the affected leg

Table 5 Comparison of statistical calculations in which the measurements of strength and endurance in the affected leg are related to the unaffected leg

	I	II	III
No. of patients	53	21	24
Isometric strength	$t=6.42$ $P<0.001$	$t=3.18$ $P<0.01$	$t=2.1$ $P<0.05$
Mean decrease	30.6%	12.9%	10.5%
Dynamic endurance	$t=5.4$ $P<0.001$	$t=4.43$ $P<0.001$	$t=1.99$ $P<0.05$
Mean decrease	33.0%	19.5%	12.2%

Group I Fractures treated by direct nailing

Group II Conservatively treated fractures in children.

Group III Fractures treated by indirect nailing

t = Student's test.

in isometric strength and dynamic endurance, respectively. The patient having a 4 cm shortening also had a decrease of strength, of 30 per cent and 75 per cent, respectively.

DISCUSSION

As parameters in evaluating the results of treatment of fractures of the femoral shaft we have introduced measurements of muscle strength and endurance. The present study is a continuation of our investigations into quadriceps strength in patients treated for fractures of the femoral shaft.

The 1972 series included 53 adults treated by open reduction and direct intramedullary nailing by the method of Street-Hansen (Group I). The series from 1974 comprised 33 children treated by traction (Group II). Danckwardt-Lillieström & Sjögren, in 1976, used the same principle for measuring strength and endurance in a series of 23 patients, but only 17 of them had been treated by intramedullary nailing alone. In the present study we followed 24 patients with fractures of the femoral shaft without other injuries (Group III).

Table 5 lists the results of isometric strength and dynamic endurance measurement of knee extension in patients with fractures of the femoral shaft — treated by the three methods mentioned above.

The decrease of dynamic endurance was greater than that of isometric strength cases. The ratio between these two measurements was approximately the same in all series. On the other hand, the decrease in isometric strength as well as in dynamic endurance in the affected leg was considerably greater in group I patients, treated by reduction (mean about 30 per cent) than in group III patients, treated by closed reduction and indirect intramedullary nailing (about 12 per cent). The results for group II (treated by traction) are intermediate between those for groups I and III, but closer to the latter.

Conclusion

In group I from 1972, treated by direct nailing, the mean decrease in strength was about 30 per cent, which is definitely abnormal. In the present material treated by indirect nailing the mean decrease was about 10 per cent, and in patients under 15 years of age it was considerably less. The difference is within the range of normal symmetrical muscle groups (Heebøll-Andersen, 1964). In other words, the indirect intramedullary nailing has shown clear advantages over the direct, open method. Formerly, moreover, obviates further transection of the muscles and reduces the risk of secondary infection at the fracture site.

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HIGH TIBIAL OSTEOTOMY FOR RHEUMATOID ARTHRITIS OF THE KNEE

A One to Six Year Follow-Up Study

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Although high tibial osteotomy for osteoarthritis of the knee joint is now well recognized, its place in the management of rheumatoid arthritis of the knee is much less well established. Thirty-six rheumatoid knees were reviewed 1 to 6 years following tibial osteotomy. The results were 42 per cent good, 39 per cent satisfactory and 19 per cent poor. No patient remained free of pain for more than 3 years, and recurrence of pain was not always associated with recurrence of deformity. Varus knees did considerably better than valgus knees despite some technical errors. Maintenance of a normal femoro-tibial angle range of 164° to 177° at follow up was important but not as important as maintenance of the knee. The beneficial effect of tibial osteotomy in rheumatoid arthritis of the knee seldom lasted more than 3 years. At the time an increasing number of bad results were seen. It was concluded that high tibial osteotomy was a satisfactory procedure for rheumatoid arthritis of the knee but its efficacy was not comparable to that seen in osteoarthritis nor was its effect long-lasting.

Key words: rheumatoid arthritis, knee, tibial osteotomy

Accepted 23 ix.77

High tibial osteotomy for osteoarthritis of the knee is now a well recognized procedure (Wardle 1962, Coventry 1965, 1973, Bauer et al 1969, Jackson et al 1969, Jackson & Waugh 1974, Harding 1975). It is also known that good results can last up to 10 years (Seal & Chan 1975). The efficacy of tibial osteotomy in the management of rheumatoid arthritis of the knee, however, has not been well established. The purpose of this report is to assess the value of tibial osteotomy in rheumatoid arthritis of the knee and to evaluate the importance of maintaining the correction within Bauer's femoro-tibial angle range of 164° – 177° (Bauer et al 1969). The femoro-tibial angle is defined as the lateral angle formed between the axes of the femur and

tibia in the longitudinal plane during weight bearing.

PATIENTS AND METHODS

From June 1969 to August 1974 35 patients underwent high tibial osteotomy for rheumatoid arthritis of the knee in Bath. Two patients had bilateral osteotomies of which one procedure was outside the period of study. Thirty-six knees are thus available for assessment. No patients were lost to follow-up and all were seen and examined by one of the authors (JPP). The indications for osteotomy were pain, deformity and instability. The length of follow up is from 1 to 6 years with an average of 3 years.

operative profile

There were 28 females and 7 males with an age range of 22 to 78 years, the average age being 61 years. Twenty-four patients were seropositive at time of surgery and the same number of patients were on steroid medication. The duration of rheumatoid arthritis at operation was from 5 to 25 years. With the exception of five patients all had multiple joint involvement, often affecting the hips and feet. Preoperatively four patients used crutches (one was confined to a wheelchair). Thirteen patients had undergone surgery to the affected knee joints from 6 months to 3 years prior to osteotomy. The surgical procedures included twelve synovectomies, five being associated with patellectomies and one total femoral condylar replacement.

operative details

There were 29 valgus knees and seven varus knees. The deformities as measured by Bauer's method of the tibial angle on weight-bearing ranged from 10° to 193°. With one exception, closing wedge osteotomy was the method used for correction of the deformity. Two osteotomies were carried out above the tibial tubercle since the deformities were considered too great for correction above the tubercle. Two patients had synovectomy at the

joint and were immobilized for a period of 6 to 8 weeks.

Immediate postoperative radiographs showed that all knees were corrected to a femoro-tibial angle range of 165° to 180°, thus being within the normal range of 160° to 180° for normal knees. At review the range had widened to 150° to 190°.

indications

There was no indication for surgery in any of the joints.

method of assessment

At review standard radiographs of the knees were taken together with weight bearing views. The femoro-tibial angle was measured. Rheumatoid activity was assessed both clinically by estimation of the rheumatoid factor and sedimentation rate. Examination of the knee included measurement of range of movement, assessment of collateral stability and synovial activity. Analgesics intake was noted. In rheumatoid arthritis multiple joint involvement

often makes specific assessment of individual joints difficult and at the same time probably not very meaningful. Pain relief, however, can be assessed. Thus Coventry (1973) in his evaluation of rheumatoid knees graded results according to pain relief only. We have graded our results as good, satisfactory and poor according to the following criteria:

Pain

- Grade 1 No pain in knee
- Grade 2 Occasional analgesics for knee pain
- Grade 3 No change/worse

Mobility

- Grade 1 Improved
- Grade 2 No change
- Grade 3 Decreased

Function

- Grade 1 Considerable improvement
- Grade 2 Improved
- Grade 3 No change/worse

GOOD

All grade 1, one grade 2, no grade 3

SATISFACTORY

One grade 1, all grade 2, no more than one grade 3

POOR

No grade 1, two or more grade 3

RESULTS

Of the 36 knees assessed 15 knees were classified as good (42 per cent), 7 as satisfactory (19 per cent) and 14 as poor (39 per cent).

Pain relief

At review eight patients did not complain of pain in their knees. It is important to note that none of these eight patients had had the osteotomy for more than 3 years. Nine patients stated that their knees were much less painful than before surgery and they only took occasional analgesics for knee pain. Four replied outright that surgery had been totally unsuccessful as regards pain relief. Another eight patients had already undergone further surgery to their knees with pain as the main reason for revision surgery.

The efficacy of tibial osteotomy for pain relief in rheumatoid knees is thus poor and

contrasts sharply with the results in osteoarthritis. Our findings in this series are not specifically related to the general level of rheumatoid activity among patients since there was an equal distribution of patients with positive RA Latex and raised sedimentation rate at the time of surgery and at the time of review.

The most important finding as regards pain relief is that in no knee did pain relief last for more than 3 years. Indeed with passage of time increase in pain is more than likely

Range of movement

Comparing the range of movement measured at follow up with that recorded preoperatively, 24 knees (66 per cent) had an unchanged range of movement. Five knees had an increased range, the maximum being 50°, all five knees were graded good. Seven knees had a diminished range, the maximum being 70°. Of these five were graded poor and two satisfactory, one of the latter knees became ankylosed following surgery with concomitant decrease in pain.

Fifteen knees had a fixed flexion contracture at follow up with a range of 5 to 30° (average 11°). There seems to be no definite correlation with results except when the deformity is severe. There was one case of recurvatum of 10° at review giving a poor result.

Functional assessment

In contrast to osteoarthritis where functional improvement is excellent following high tibial osteotomy, only 10 out of 35 patients (36 knees) admitted to definite improvement following surgery. Patients' acceptance of a second and similar procedure is a good index of subjective assessment and in this series only two patients had subsequent osteotomy of the contralateral knee. In one series of osteoarthrotic knees (Seal & Chan 1975) 11 out of 47 patients had bilateral osteotomies. Another indication of relative lack of functional improvement is that four patients required crutches and three were

confined to wheelchairs at review as to four and one, respectively, before.

Femoro-tibial angle at follow-up

Immediate postoperative radii showed that all knees were correct femoro-tibial angle range of 165°-170° without exception within the femoro-tibial angle range for normal knees. At follow up the range had widened to 155°-190°.

The femoro-tibial angle at follow up is shown in Figure 1, preoperatively values being indicated by brackets.

Preoperatively valgus knees There was a proportionately equal distribution among good, satisfactory and poor groups with a normal femoro-tibial angle at follow up. This is in distinct contrast with knees where maintenance of a normal femoro-tibial angle is vitally important for a good result. In one series, all poor results followed valgus knees (Chan 1975).

Preoperatively varus knees There were seven varus knees in this series but of interest to note that firstly, a

F.T. Angle	Good	Satisfactory	Poor
90°	G G		
105°	100% G G		P
120°	G G	S S	P P P
135°	G G G	S	P P
150°	G		P
165°	G G	S	P
180°			P
195°		S S	P
210°		S	P P

Figure 1 Femoro-tibial angle at follow-up (G)(S)(P) = knees in varus preoperatively G S P = knees in valgus preoperatively

ber belonged to the good group (five out of ten) and secondly, despite undercorrection results remained good (Figure 2) The numbers are too small for definite statement the results suggest that varus knees do better than valgus knees. This finding applies to knees with severe articular damage at time of operation (Figure 2) The same observation has also been made in coarthrotic knees (Harding 1975)

Results

Fourteen knees were assessed as poor at review (39 per cent) Of these eight had undergone further surgery at 1 to 6 years following tibial osteotomy The reasons for revision surgery were recurrence of pain in all joints deformity in four and instability in one patient Some failures were technical in nature

There was one case each of the osteotomy being carried into the joint, a staple protruding into the joint and over-correction. Five knees were under-corrected even though the immediate postoperative radiographs showed correction to be within Bauer's femoro-tibial angle. This was due to the fact that collateral laxity was not recognized at operation resulting in apparent rather than real correction of the deformity (Figure 3) Previous surgery to the knee prejudices the results, seven out of thirteen of these knees were graded poor at review (55 per cent) The reason for this is not clear since analysis of clinical details and radiographs showed that this group did not contain an undue number of radiologically severely affected knees which might have accounted for the high percentage of failure

Three knees showed radiologically mild rheumatoid arthritis at the time of surgery but subsequently deteriorated rapidly with an

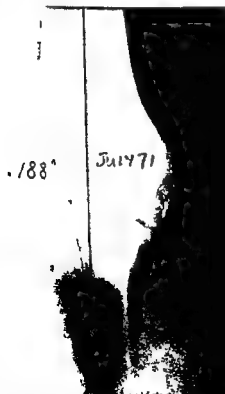


Figure 2 Varus knee Preoperative femoro-tibial angle 188° July 1971 Follow-up angle 182° July 1975 Note under-correction Result good

eventual poor result. The knees however remained well corrected at the time of review.

Up to 3 years postoperation there is a bias towards a good result, after which time a progressive worsening of results is seen usually associated with recurrence of pain and less frequently with recurrence of deformity (Table 1).

Good results

Fifteen knees were graded as good (42 per cent). Five of these were preoperatively varus knees and measurement of femoro-tibial angle at review showed that they were still in varus. Of the ten preoperatively valgus knees graded as good at review, one had been over corrected and the rest had been maintained within a normal femoro-tibial angle range. Three knees in the good group were clinically and radiologically severely affected at the time of

operation but subsequently did well. There is no obvious explanation for this except that the knees were either well corrected and correction was subsequently maintained or that the knees were in varus at time of operation. Sloping joint line was not significant pre- or post-operation. The femoro-tibial angle was within normal limits.

DISCUSSION

Corrective high tibial osteotomy has gained an important place in the management of osteoarthritis of the knee and good results of 70 per cent or more can be expected to be maintained for many years after operation (Coventry 1973, Seal & Chan 1975). There is also general agreement on the importance of correction of the deformity to a range of 10° to 15° (Bauer's femoro-tibial angle (Bauer et al. 1971)).

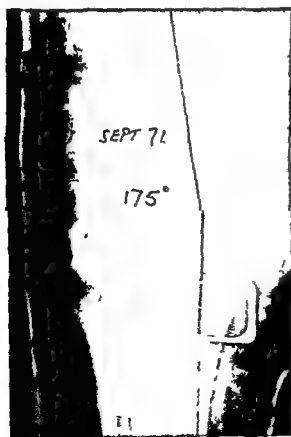


Figure 3 September 1971 Postoperative angle 175°. Note correction is apparent rather than real & lateral collateral laxity December 1971 Femoro-tibial angle out of plaster cast 163°. Result poor

uris & Kostuk 1970) Information on the value of tibial osteotomy for rheumatoid knees is scarce. Of the 474 knees evaluated by Coventry (1973), Jackson & Waugh (1974) and Harding (1975), 37 were rheumatoid knees. In the present study while small it is therefore one of the largest series confined specifically to rheumatoid knees. It is clear from this study that the results of osteotomy in rheumatoid knees differ from those obtained in osteoarthrotic knees as follows

Pain relief is of much shorter duration. There is no knee in this series with pain relief lasting more than 3 years. In osteoarthrotic knees, recurrence of pain is usually associated with recurrence of deformity and this is not necessarily so in rheumatoid knees.

Functional improvement is by no means as dramatic as that obtained in osteoarthrotic knees, nor is the duration of improvement maintained for as long a period of time.

This is true both subjectively and objectively. It is important to point out, however, that in rheumatoid arthritis any gain in function, albeit minor, is a real asset to an already crippled patient and any relief from pain, even of limited duration is advantageous in reducing disability.

Maintenance of the femoro-tibial angle, though important, is not as vitally significant as in osteoarthrosis of the knee.

The reason for this is probably multifactorial since rheumatoid arthritis is a generalized disorder and there are more problems involved than simple mechanical correction of varus or valgus deformity. Varus knees treated by osteotomy require further analysis, since if our results are reproducible in a larger series then high tibial osteotomy for this deformity can lead to the same success rate as in osteoarthrotic knees.

It is vital to be meticulous with operative details. As bone in rheumatoid patients is usually osteoporotic, osteotomy is technically easy but may readily produce a tibial plateau fracture or penetration of the

joint. Furthermore, staple fixation can be difficult to achieve and may result in their insertion through the subchondral bone into the joint in error.

5 Steroid medication in this series had no significant effect on results at review. No problems were observed as regards wound healing, bone union and infection associated with steroid intake. There was one case of infection in 36 knees.

6 Mild and burnt out rheumatoid and varus knees appear to do best following high tibial osteotomy. Advanced disease should be avoided. A sloping joint-line is not a contra-indication, provided good alignment is obtained at operation. One should aim to over correct rather than under correct, as in osteoarthrotic knees. Due allowance for collateral instability is necessary and can only be checked and avoided by radiography at operation. A few knees moderately diseased at operation, subsequently deteriorated rapidly, both clinically and radiologically. At present no means of predicting these changes is known, a solution to this problem would greatly improve results.

7 The following categories tend to give poor results, viz, knees with severe fixed flexion deformity, with marked collateral instability, and those subjected to previous surgical procedures. Valgus knees tend to do less well than varus knees. Valgus, if under corrected, disposes to failure. Radiologically advanced rheumatoid joints will probably not respond.

8 Approximately 60 per cent good and satisfactory results were obtained in this

Table 1 Influence of time elapsed since operation on results

Length of time since operation	Good	Satisfactory	Poor
Up to 3 years	11	4	4
More than 3 years	4	3	10

series, with a follow-up of 1 to 6 years. However, as is shown in Table 1, the number of long-term good and satisfactory results beyond 3 years are considerably reduced. If the results of tibial osteotomy are to be compared with other procedures such as double osteotomy (Benjamin 1969) and total joint replacement, the follow-up period must be at least 3 years since prior assessment will give a disproportionate number of good results.

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E SAAB JIG: AN AID IN HIGH TIBIAL OSTEOTOMY

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To increase the precision of high tibial osteotomy a surgical tool has been developed. The instrument is described. The precision obtainable using the instrument is found to be significantly ($P < 0.001$) higher than that obtained when operating without the instrument.

Key words: gonarthrosis, high tibial osteotomy, surgical tool

Accepted 1.1.77

High tibial osteotomy is commonly used in the treatment of moderately severe gonarthrosis with varus or valgus deviation. The size of the wedge to be removed to correct the deviation is determined in various ways in different clinics (Devas 1969, Coventry 1973, Maquet 1976, Edholm et al 1976 and 1977, Myrneris & Wennberg 1977). Freedom from pain is five times more likely in well-corrected patients than in patients who have been either over- or undercorrected (Hagstedt 1974). A necessary condition for a good correction is that the wedge removed is exactly of the size determined preoperatively. To increase the possibility of removing exactly the predetermined size of wedge at high tibial osteotomy, a surgical tool has been developed in the Department of Orthopaedic Surgery, Linköping, Sweden, in co-operation with AB-Scania. The instrument has been called E SAAB jig. Its construction and function can be seen in Figures 1-7. The precision of the instrument has been examined in connection with a clinical study of gonarthrosis.

METHOD

The size of the wedge that was actually removed at operation was determined by measuring the angle between the long axis of the tibia and a tangent to the articulating surfaces of the tibial condyles on frontal x-rays of the knee, taken before and immediately after the operation. The actual size of the wedge removed was compared with that intended. The intended wedge size was determined by three-point-measurement (Edholm et al 1976 and 1977, Myrneris & Wennberg 1977). The difference between the intended wedge size and the size of the wedge actually removed has been used as a measure of the precision of the surgical method.

MATERIAL

The difference between intended wedge size and actual wedge size was determined in 56 patients operated on using the SAAB jig (group A) and in 40 patients operated on without the jig (group B). In the latter operations, prefabricated models of the wedge or the method in which 1 mm on the cortical surface corresponds to 1° of wedge were used as an aid in determining the wedge size to be removed.

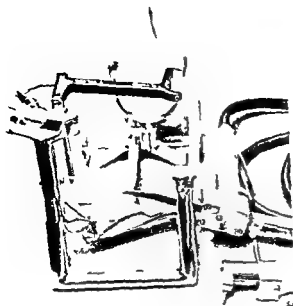


Figure 1 The jig consists of a metal frame for three-point suspension of the lower leg. An articulated arm, that directs a saw in a well defined plane, is mounted on this frame



Figure 2 The leg is suspended by two metal points that are drilled into the bone laterally and medially at the knee and by a circular holder that can be tightened around the ankle



Figure 3 With this mechanism the position of the wedge can be determined. The articulated saw arm is in positions 1 and 2 respectively (see arrows) a wedge is removed the size of which can be read on the scale mechanism



Figure 4 The osteotomy is carried out

RESULTS

The results of a comparison between surgical methods are shown in Table 1. It has been possible to reduce the percentage corrections (difference $> 1/6^\circ$) from 2.1 to 0.5. A statistical comparison of the mean differences between the intended and actual wedge size in the two groups showed a significant improvement in favour of the SAAB jig ($P < 0.001$). The SAAB jig is easy to use and no injuries to vessels or nerves have been observed.



Figure 5 After the wedge has been removed and the ends of the osteotomy have been approximated a saw is changed for a special drill and two holes are bored parallel to the line of the osteotomy



Figure 6 The osteotomy is stabilized with one or two staples



Figure 7 Postoperative x rays

Table 1 The difference between intended wedge size and actual wedge size measured immediately postoperatively

Group/Diff	/0°-2°/	/2°-4°/	/4°-6°/	>/6°/
A	53.3%	26.8%	12.5%	5.4%
B	30.0%	22.5%	25.0%	22.5%

DISCUSSION

It is still not known with any certainty what is the optimal degree of correction in high tibial osteotomy. In addition, the correction can either increase or decrease while the osteotomy is healing. Nevertheless, it seems that one prerequisite for a good correction is that the size of the wedge removed at operation is as close as possible to the predetermined size and we have found the SAAB jig to be of decided value in achieving this.

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OSTEOCHONDRITIS DISSECANS OF THE TALUS

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Nineteen patients showing radiological subchondral changes in the trochlea tali are submitted. In 16 cases the changes were osteochondritis dissecans, either with sequestra or with multilocular cysts, and in three cases so-called synovial cysts. The site was in 13 cases the upper medial and in five cases the upper lateral angle of the talus, and in one patient both. In five of the six lateral cases symptoms had started following trauma while this applied to only five of the 13 medial cases. The three solitary cysts showed marked similarity to the other cases with respect to symptoms, signs, operative findings, as well as possible traumatic aetiology.

Key words: osteochondritis dissecans, trochlea tali

Accepted 1 ix.77

Osteochondritis of the Talus

During the period 1970-1976 a total of 19 patients showing radiological changes subchondrally in the trochlea tali were treated in

the Department of Orthopaedic Surgery, Rigshospitalet, Naestved. According to the literature osteochondritis dissecans is uncommon at this site. However, the fairly large number of patients presenting during the 7-year period appears to indicate that the disease is more common than previously assumed.

In some cases the changes represented osteochondritis dissecans, in others solitary subchondral cysts. In the literature these two conditions are discussed separately, but in the present series there were so many items of similarity that it may be asked whether they are in fact two different manifestations of the same disease.

PATIENTS AND METHODS

All 19 patients had definite radiological changes subchondrally in the talus. In addition, there was a

case that showed, at operation, a detached flake of cartilage from the articular surface of the talus and two in which the cartilage was merely soft and a bit discoloured in one area, however, no radiological

The mean age at diagnosis was 36 years, range 15-63 years. The mean age of the males was 13 years younger than that of the females of whom only two were under 50, whereas no man was over 50.

All the patients had pain provoked by weight-bearing in several cases only intermittently, and five patients also suffered occasionally from rest pain. In four cases there were episodes of locking in the ankle joint, and another four patients had a sensation of sometimes "missing" a step. Clinical signs were modest. In eight patients absent. In four cases there was tenderness anteriorly or posteriorly to the malleolus in which the changes were localized. Six patients felt tenderness on forced movements of the ankle joint, and in five there was slight limitation of motion. The mean duration of symptoms was rather more than 2 years.

An adequate trauma was reported by nine patients. Eight of them had sustained fairly severe distortion traumas and suffered from persisting pain until diagnosis, from 2 months to 3 years later. In four cases an X-ray examination had been done primarily after the distortion but no changes had

Table 1 The difference between intended wedge size and actual wedge size measured immediately postoperatively

Group/Diff	/0°-2°/	/2°-4°/	/4°-6°/	>/6°/
A	55.3%	26.8%	12.5%	5.4%
B	30.0%	22.5%	25.0%	22.5%

DISCUSSION

It is still not known with any certainty what is the optimal degree of correction in high tibial osteotomy. In addition, the correction can either increase or decrease while the osteotomy is healing. Nevertheless, it seems that one prerequisite for a good correction is that the size of the wedge removed at operation is as close as possible to the predetermined size and we have found the SAAB jig to be of decided value in achieving this.

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examination technique in *International Orthopaedics (SICOT)*.



Fig. 3 Unilocular cyst in the upper medial angle of talus

In the only finding was frayed and soft cartilage, in three cases the cartilage was definitely eroded, and in seven cases it was more or less chiselled. The approach to the joint was most often chiselling off the medial malleolus after first making a burr canal up through the malleolus. At the operation, the malleolus was fixed with a screw. In cases where the disease was localized laterally, the approach was anterior or posterior to the lateral malleolus. In all cases surgery was done into the site of osteochondritis or the cysts, except in one case in which a cyst was filled with bone chips. Moreover loose cartilage was removed in six cases. Postoperatively patients wore a walking cast for 4–6 weeks.

RESULTS

Of the 19 patients one has died and one has undergone talocrural fusion. Below, this case will be excluded because of very severe preoperative osteoarthritis. In two cases the follow-up period was less than 6 months. In the remaining 15 it ranged from 7 months to more than 5 years, mean 33 months.

Eight of the 15 patients were free of pain, five had mild pain, and in two the pain was unchanged. In all cases the pain occurred only after prolonged weight-bearing, and especially when walking on rough ground. Only two had such severe complaints that occasionally they had to stay away from work. In all seven patients with pain this complaint restricted their spare time activities. Table 2 lists the results at follow-up, as regards pain related to the sites of the X-ray changes in the talus and to a possible history of trauma. Only cases having a follow-up period exceeding 6 months are included. None of the patients had subsequently received treatment.

Limitation of motion in the ankle joint was found in seven patients, equally distributed among those with and without pain. The limitation never exceeded 15° and most often affected dorsiflexion or plantar flexion, rarely pronation or supination. A couple of the patients were unable to squat properly.

Alterations in the radiological appearances from the preoperative films to exposures at follow-up were classified; in 13 of the 15 cases, into changes deep in the talus, changes on its surface, and osteoarthritic changes in the ankle joint. In five cases the changes in the subchondral bony structure had disappeared, in two the appearances were unchanged, and in six partial healing had occurred, with

Table 1 Distribution of cases according to radiological findings

	Number	Medial location	Lateral location
Segmented osteochondritis	10	6	4
Unilocular cyst	7	6	1
Multilocular cyst	3	2	1

One patient had changes on both sides of the talus, the total number of cases = 20

Table 2 Results at follow-up in relation to the site of the radiological finding in the talus history of trauma

	Symptomless	Mild pain	L:
Medially in the talus	5	3	
Laterally in the talus	3	3	
History of trauma	4	2	
No history of trauma	4	3	

invasion of somewhat sclerotic bony tissue. The contour of the surface of the bone was more even and smooth than preoperatively in three cases, unchanged in five, and in another five there was exacerbation, with collapse and a more rugged surface of the bone. Since the treatment, six patients had developed mild osteoarthritic changes, or else mild changes had progressed.

The radiological changes in the bone as well as on its surface and in the joint were identical whether the lesion was localized medially or laterally and whether or not there was a history of trauma. In cases subjected to osteotomy of the medial malleolus, healing of the malleolus was uncomplicated, and the joint surface at this site is entirely normal.

DISCUSSION

Osteochondritis dissecans affecting the talus is considered a rare condition. According to Berndt & Harty (1959) it was first reported by Kappis (1922). Without knowledge of Kappis' publication, Wolff (1926), in Denmark, reported two cases, one of which had been diagnosed as early as 1916.

From the literature up to 1957 Berndt & Harty (1959) collected a total of 151 cases. Of all these publications only three deal with more than four patients, viz., 13 (Ray & Coughlin 1947), 19 (De Ginder 1955), and 55 cases (Rodén et al 1953). The fairly large series of 55 cases was collected at the University of Stockholm (Karolinska Institutet och Sjukhuset). Thus, and the fact that 19 cases were found in 7 years in the

Central Hospital, Næstved, would indicate that the condition is not previously assumed. Several authors (Coughlin 1947, Rodén 1953) pointed out that the radiological may be difficult, and indeed this is by the present material.

The discussion concerning the osteochondritis affecting the talus differ from that concerning the knee. Of the ankle there is particularly of the role of distortion trauma and transchondral fracture. Eskesen (1953) distinction between transchondral localized in the lateral angle of the talus (19 cases) and osteochondritis dissecans to the medial angle of the talus or of the trochlea (as described by Møller 1916) in nine cases from the literature plus his own). Myhre did not feel that it was an aetiological factor. Rasmussen published one case of osteochondritis localized laterally in the talus which occurred after a distortion trauma. According to Berndt & Harty (1959) the increasing tendency to accept the traumatic genesis, and this view is supported by O'Donoghue (1966). Rodén et al (1953) assume that changes in the lateral angle of the talus are of traumatic origin, but consider that this applies to medial changes. In the present material the probable traumatic cause in five of the cases with changes in the upper part of the talus. The sixth patient had a severe distortion trauma 7½ years prior to the operation, but the symptoms did not appear until later. It is doubtful, but not ex-

tion, that the trauma may have been operative. On the other hand, a history of trauma is less common in cases having lesions medially in the talus. In the present material only five out of 14 had a history of trauma. One of them is the above-mentioned case of osteochondral fracture. A cyst developed, but not until several years later might indicate that a trauma may have sustained several years previously but it being possible to adduce a definite relationship.

In the present material patients having lesions medially in the talus did not have more or milder symptoms than those having lesions laterally in the talus as found by Rodén et al (1953).

As already stated, the X-ray films showed osteochondritis, with sequestra and also locular cysts as described by Stougård (1950). In several cases these cysts communicated with the joint. Lastly, solitary cysts were found in three cases. Several authors consider such solitary cysts a disease entity (Crane & Scasano 1967, Stadil & Rodén 1970, Dashefsky 1971, Ogden & Griswold 1972, Paaby 1973), often called solitary bone cysts. The above-mentioned authors believe that these cysts are most probably of traumatic origin. In this connection the possibility has been mentioned that the pressure in the joint forces synovial fluid down into an osteochondral fracture thereby prevents healing, and at the same time a communication with the joint may be established. There was a hint of such a communication in one of the present cases with a solitary cyst in the upper medial angle of the talus.

In the present material there was a striking similarity of osteochondritis and solitary cysts with respect to symptoms and signs as well as to operative findings. The three patients with solitary cysts were a woman aged 57 and two men aged 21 and 47. All had pain on weight-bearing, one also rest pain, but no episodes of locking or limitation of motion. After operation these cases exhibited soft, unmineralized cartilage. Thus, there is a great possibility to indicate that solitary synovial cysts and

osteochondritis dissecans represent the same disease with different manifestation or at different stages of development.

The treatment, broadly speaking fairly uniform, afforded satisfactory results with relief from symptoms in eight out of 16 patients seen at follow-up after a minimum period of 6 months. Among the others, five had pain, but milder than prior to the operation, two had unchanged pain, and in one case talocrural fusion had been required. Authors who have tried to assess conservative versus operative treatment (Berndt & Harty 1959, Rodén et al 1953) conclude that operation is definitely better. Rodén et al (1953) restrict their operative indication to patients having symptoms. In the present material the diagnosis was made in all cases on the basis of symptoms.

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fragmented adipose tissue and a small amount of fatty fluid

The *histologic examination* revealed fragments

adipose tissue showed regressive changes with small groups of foam cells, fibrosis and one fragment also included deposits of calcium

At follow-up 13 months postoperatively the patient had no complaints except for slight tenderness at the site of the heel incision. Radiograms showed bone replacement of the lesion.

Case 2 A 23-year-old woman experienced sudden pain in her left leg in December 1973, 6 months prior to admission. She could not recall any trauma. During the following months the ache persisted and was accentuated during and after walking. Also a moderate swelling of the ankle and foot was observed.

Radiography in January 1974 revealed an ovoid lytic lesion in the distal part of the tibia, with a

maximum diameter of 6 cm, within 1 cm of the ankle joint. Bone trabeculae and some calcifications could be seen within the lesion which was well demarcated without surrounding sclerosis (Figure 2). Radiographic examination was repeated in 1974 with the same result.

Diagnostic curettage with removal of the contents of the lesion was performed in May 1974 because chondrosarcoma was suspected.

Grossly the specimen consisted of adipose fragments and small pieces of bone.

Histologically the material consisted dominantly of mature adipose tissue as in Case 1. Small bone lamellae with osteoblastic or osteoclastic activity were seen within the adipose tissue. No cartilage was present.

At follow-up 13 months postoperatively the lesion was found to be unchanged. A full-thickness skin graft was therefore performed with thorough removal of the contents of the lesion.

The material revealed, as previously mentioned, areas of fibrosis and a moderate inflammatory reaction with infiltrating lymphocytes and plasmic cells were also present, probably reflecting a postoperative reaction.

At follow-up 2 years and 8 months postoperatively the patient, who worked as a nurse, complained of moderate swelling of her ankle region, more



Figure 2 Case 2 Radiograph revealing an osteolytic lesion with some bone ridges and calcifications within the lower part of the right tibia



Figure 3 Case 2 Uniform unencapsulated adipose tissue surrounding a few small lamellae of bone H&E x120

he left, operated side. Clinically there was no swelling or tenderness and no restriction of ankle movement. Radiograms showed that the lesion had replaced by normal bone.

DISCUSSION

• Lipomatous tumours are rare. Occasional cases of liposarcoma primarily arising in bone have been described (e.g. Jenson 1955, Catto & Stevens 1963, Lerman 1964). The incidence of lipoma in bone is, according to Dahlin (1970), 1 in 1000 cases of bone tumours. Also intraosseous angiolipomas and paraosteal lipomas have been reported (Salzer & Gotzmann 1963, Jenson 1965). The most common location of intraosseous lipomas is the metaphyseal parts of long bones, including the present two cases, but of 22 cases have been located at such sites. It is interesting that of the remaining five patients four presented with a lesion in the calcaneus. Radiographically an intraosseous lipoma has the appearance of a well-delimited osteolytic lesion within the marrow cavity, sometimes with bone ridges and/or calcifications as in the cases described above. It is noteworthy that two out of three lipomas in the calcaneus previously reported showed a central sclerotic focus as in the present Case 1, which probably responded to the regressive changes with deposits of calcium found histologically (cf. Jenson & Weitzner 1974, Poussa & Holmstrom 1976). The histologic picture in the two cases

described here was that of mature adipose tissue, not different from ordinary fat marrow and similar to that of a localized focus of osteoporosis (cf. Dahlin 1970). The diagnosis of intraosseous lipoma can therefore not be based on the histologic appearance alone but must also include clinical information and radiographic appearance.

Curettage and filling of the cavity with cancellous bone seems to be the treatment of choice if the lesion causes pain or a correct diagnosis cannot otherwise be made.

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A CASE OF SEPTIC ARTHRITIS IN MULTIPLE JOINTS DUE TO *BACTEROIDES FRAGILIS* IN A PATIENT WITH RHEUMATOID ARTHRITIS

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A case of arthritis in multiple joints due to *B. fragilis* sp. f. described. The patient was a 55 year-old man badly disabled by his arthritis. The patient's immune response to the isolated strain was and a significant titre reduction during the course of the disease observed.

Key words: polyarthrititis, septic anaerobic infection, Bacteroides

Accepted 9 x.77

Anaerobes are nowadays isolated from most types of clinical specimens and this has raised the question of what role these bacteria play in different infections. Most anaerobic bacteria infecting human tissue are part of the normal flora. Anaerobes often act as opportunists infecting patients in special risk groups with weak immunological defence. The debilitated patient with rheumatoid arthritis appears to be unusually susceptible to bacterial infection and may develop septic arthritis which may be fatal if not adequately treated (Brit med J 1976). In 1969, Ziment et al made a review of the literature and found reports of 47 cases of septic joint infections involving anaerobes. Brorson et al. (1975) reported a case of pyogenic arthritis due to *Bacteroides fragilis* in a patient with rheumatoid arthritis with significant changes in antibody titres during the course of the disease.

In this report a patient is described with septic polyarthrititis due to *B. fragilis*.

CASE REPORT

The patient was a 55 year-old man with rheumatoid arthritis. He was badly disabled but had earlier been treated with steroids and butazone. At the time of the infection he was taking indometacin and salicylic acid.

The patient was admitted to the hospital with high fever which had lasted 3 days and of acute arthritis in his left shoulder. Treatment with penicillin V had been started. Probenecid treatment was added. Pus from the affected joint grew *B. fragilis* ssp. *fragilis*. Initially the patient responded well to treatment, but his temperature rose as an abscess formed on the left upper arm. Lincomycin treatment was started and the arthritis developed in the patient's right knee.

elbow and there were signs of incipient osteomyelitis on his right upper arm. Subsequently he grew *B. fragilis* resistant to penicillin. A change of treatment to clindamycin and rifampicin, as well as surgical drainage and irrigation of the affected joints with physiotherapy, the patient recovered.

Laboratory methods

Cultivation procedures All specimens for culture were transported to the laboratory in a transport medium, or, when aspirated, in anaerobic culture bottles. They were cultured initially using conventional laboratory techniques as well as anaerobically using the Gas Pak system (BBL, Maryland, USA). The methods of isolation and identification of anaerobic bacteria are described by Holdeman & Moore (1973) and followed. The subspecies of *Bacteroides* were identified by fermentation tests, using the API system (API, Plainview, N.Y., USA). For virulence testing the technique of Ericsson & Sjöberg (1971) was used. The agar was the same as for original anaerobic cultivation. The bacteria were carefully suspended in sterile saline and inoculated on each plate. Excess suspension was discarded and the plates were dried at 37°C. Sterilized discs containing the antibiotics (AB 10, Stockholm, Sweden) were applied to the surface and incubated for 48 h at 37°C in anaerobic medium using the Gas Pak system.

Specimens Seven blood samples were drawn from the patient between October 1975 and July 1976. Sera were examined for antibodies against the infecting strain of *B. fragilis ssp. fragilis*. Serum from five healthy laboratory workers, 20-30 years of age, was used as control. Serum samples were frozen in small portions and stored at -20°C until used.

Immunological procedures Indirect immunofluorescence test (IFL), tube agglutination and passive haemagglutination (PHA) were performed as described by Danielsson et al. (1974a). Fourfold or greater changes of titres were considered clinically significant (Danielsson et al. 1974b).

RESULTS

B. fragilis ssp. fragilis was isolated from the left shoulder joint, the left upper arm, the right elbow and the right knee. All blood cultures were negative. The isolated strain was sensitive to doxycycline, erythromycin, lincomycin, clindamycin and metronidazole. It was resistant to ampicillin, penicillin, gentamicin, cephalixin, sulphonamides and trimethoprim/sulphamethoxazole.

Table 1 shows the immunological response against the isolated *Bacteroides* strain determined by three different methods. High titres were found with all methods at the time of the beginning and the peak of infection. The titres decreased significantly during the recovery of the patient. Control serum did not show any antibody titres against the *Bacteroides* strain used as antigen.

Four of the patient's sera were also tested against three heterologous strains of *B. fragilis ssp. fragilis* isolated in this laboratory from other types of infection. Only the IFL technique was performed. The result is shown in Table 2.

Table 1. Antibody titres in patient's sera against the isolated strain of *Bacteroides fragilis ssp. fragilis*

	Date of serum sample							Control serum
	1975 7/10	1975 22/10	1975 5/11	1975 12/11	1976 14/1	1976 7/4	1976 24/6	
Indirect immunofluorescence	160*	160	80	40	80	40	40	20
Tube agglutination	320	ND†	80	ND	40	ND	ND	ND
Passive haemagglutination	320	160	80	20	40	ND	20	ND

* Reciprocal titres

† ND = Not Done

Table 2 Antibody titres of patient's sera against the homologous strain and three heterologous strains of *B. fragilis* ssp. *fragilis*

Strain no	Date of serum sample			
	1975 7/10	1975 5/11	1976 14/1	1976 24/6
Homologous strain	160*	80	80	40
3559	80	160	80	20
3851	80	80	80	20
3686	160	160	160	40

* Reciprocal titres.

DISCUSSION

Though anaerobic infections are not common in patients with rheumatoid arthritis one has always to consider the possibility of an opportunistic infection in this risk group. Steroid treatment of these patients is a contributing risk factor. It is obvious that the isolated *B. fragilis* strain was responsible for the infection in this case.

Since the sensitivity to penicillin decreased during the therapy the treatment was changed to clindamycin and metronidazole. Most *Bacteroides fragilis* strains are resistant to penicillins. Unfortunately metronidazole was not available for sensitivity testing at the time of this study, but most *Bacteroides fragilis* strains isolated later in this laboratory were sensitive to this agent. Patients with bacteroides infections have been treated with metronidazole with success (Tally et al. 1973).

Elevated antibody titres against an organism show an engagement of the immunological defence indicating that the isolated strains play a role in the infection, as was seen in this case.

Table 2 shows that heterologous strains of *Bacteroides fragilis* ssp. *fragilis* cross-react with the isolated strain from this patient. Titres against the heterologous strains follow those against the homologous strain not differing more than one step upwards or downwards. Immunological methods will probably be of great value in the future in

establishing the role of anaerobes. The IFL-technique seems to be a satisfactory method of the methods we have used in this study. It is fast and does not require bacterial cultures. When a *Bacteroides* infection is suspected serum from the patient could be immediately tested against a large number of strains. This would allow the clinician to obtain a rapid answer before an organism can be isolated from the specimen.

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PROCEEDINGS OF THE SWEDISH ORTHOPAEDIC ASSOCIATION

Borås, May 12-13, 1977

EDITOR BO E NILSSON

GUEST LECTURE

DECREASED ABDUCTION OF THE HIP JOINT IN INFANTS

K Palmén
Falköping

In 206 infants, in whom CDH had not been detected in the neonatal period, a later diagnosis revealed a decreased abduction in no less than 127 cases. However, this condition is not always related to CDH. Contracture of the adductors of the hip in infants is probably in many instances caused by habitual, supine - sideways position. In Sweden, infants have been traditionally kept in the supine position. It could be demonstrated that 20 per cent of children kept in this position had a decreased range of abduction motion whereas only a few children, kept in the prone position, had a decreased abduction. The range of decrease was 10-30°. Radiograms of these children could be misleading in that the child is not in a correct position on the X-ray table. Otherwise, the children's hips are radiologically normal. A good method of preventing this symptom, which may be wrongly interpreted as CDH, is lying the child in the prone position.

MECHANICS AND SYMPTOMS FOLLOWING KNEE INJURIES

O Lindahl
Linköping

The occasionally poor relationship between objective findings and subjective symptoms in various orthopedic conditions is exemplified. The anterior cruciate ligament does not by itself stabilize the knee joint in a sagittal direction. Cruciate ligament surgery is a very doubtful procedure in that the relationship between the symptoms, the condition of the ligaments and the postoperative improvement has not been verified. Objective measurements of the mechanical properties of the knee joint before and after surgery should be recorded in order to evaluate the results

of surgery which may not necessarily be in the opinion of the patient.

MEASUREMENT OF SAGITTAL INSTABILITY OF THE KNEE JOINT FUNCTIONAL POSITION

L-E Sylén
Linköping

In 10 patients with a positive drawer knee injury, the medio-posterior aspect of capsule was tightened by a surgical procedure described previously. The subjective and objective results were good. Also, the sagittal stability measured in 90° flexion improved. However, 1 year thus variable did not differ greatly from preoperative measurement. The cause of the discrepancy between a lasting clinical improvement and a temporary improvement of joint stability may be that the 90° flexion position is not ideal for measuring the drawer sign, since in this position and running knee flexion rarely occurs. Therefore, an instrument for objective measurements of sagittal knee stability in various degrees of flexion has been designed and proved valuable in preliminary studies.

RESULTS OF SURGICAL REPAIR OF LIGAMENT INJURIES

V Surén & L Ottosson
Borås

Thirty-three recent and 42 chronic ligament injuries were re-investigated 2-11 years after operation. The injuries were in most cases combined, most commonly anterior cruciate and medial collateral ligament ruptures. A very significant positive correlation between the

1 subjective stability The subjective improvement was related to the quadriceps force. After operative treatment recent injuries were significantly more often improved than chronic ones. All residual symptoms, except for the feeling of instability, were more common in those patients who had been operated on for chronic injuries. Radiological signs of arthrosis increased in the period of observation in chronic cases but not in recent cases. The various qualities of stability are related — one single measurement of stability is not relevant. Early operation and total repair of all structures is recommended.

THE RESULTS OF PARTIAL PATELLAR TENDON TRANSPOSITION FOR LATE PAIR OF ANTERIOR CRUCIATE LIGAMENT RUPTURE

Dolk, S Hallberg & U James
Lund

Twenty-five patients operated on with reconstruction of the anterior cruciate ligament, using a transplant obtained from the patellar tendon, were re-investigated after an average observation time of 33 months. Twenty-three of the patients considered themselves improved in spite of the fact that more than half still had a positive drawer-sign. There was no significant relationship between the results with regard to objective knee stability and subjective improvement. With increase in the period of time from surgery the results tended to deteriorate. The time interval injury-operation also appeared to be of importance.

RESULTS FOLLOWING CRUCIATE LIGAMENT RECONSTRUCTION

Forty-four patients operated on with reconstruction of the anterior cruciate ligament, using a transplant obtained from the patellar tendon, were re-investigated after an average observation time of 33 months. Twenty-three of the patients considered themselves improved in spite of the fact that more than half still had a positive drawer-sign. There was no significant relationship between the results with regard to objective knee stability and subjective improvement. With increase in the period of time from surgery the results tended to deteriorate. The time interval injury-operation also appeared to be of importance.

RECONSTRUCTION OF THE ANTERIOR CRUCIATE LIGAMENT

E Eriksson
Stockholm

Four modifications of Jones' procedure were compared. Eighty per cent of the knee joints were stable at the 1-year follow-up, using a modification that included a new drill guide. A detailed description of the operative technique is published in *Injuries of the Ligaments and their Repair*, ed. by G Chapchal, pp 130-142, G Thieme, Stuttgart, 1977.

RECONSTRUCTION OF INVETERATE POSTERIOR CRUCIATE LIGAMENT INJURIES

A Stenström
Lund

Five patients, all with a posterior drawer-sign, were operated on. The semi-tendinous tendon with bony attachment was used for reconstructing the posterior cruciate ligament in its original position. Four of the patients had improved with regard to instability, subjectively and objectively, three could participate in soccer, and one (a woman) did not improve.

ACUTE ARTHROSCOPY

E Eriksson
Stockholm

Fifty consecutive acute knee injuries were examined arthroscopically. The injuries, 35 total or partial anterior cruciate ligament injuries, five bucket handle and four other meniscal lesions, two radiolucent chondral loose bodies and two cases of pigmented villonodular synovitis, could be easily diagnosed and treated while under the same anesthesia. Acute arthroscopy is the quickest and most reliable method with which to obtain an accurate diagnosis.

KNEE INJURIES IN SOCCER PLAYERS

A Roos & G Andersson
Göteborg

One hundred previously active or still active soccer players, aged 30-40, were compared with 108 age-matched controls, selected to represent the male population of the city of Göteborg. A history of knee injury was found in 56 per cent of the football players, and in 17 per cent of the controls. Knee symptoms were present in 65 and 34 per cent, respectively. The most common injury in both series was rupture of a semilunar

cartilage - 29 per cent in the football players, 6 per cent in the controls. Sixteen per cent of the football players had ligamentous injuries as compared with 4 per cent in the control series. Instability was found in 18 knees among the football players and in 16 knees in the control series. Reduced joint space was found medially in four subjects, all soccer players.

COMPARATIVE STUDIES OF QUADRICEPS TRAINING MODELS AFTER KNEE SURGERY

L. Peterson, G. Grimby, E. Gustavsson & P. Renström
Göteborg

The effect of quadriceps exercise was tested in three groups of patients after knee injury and operation: one group used an isokinetic training device, one group a quadriceps exercise table and one a standard home program. The exercise program was carried for a period of 6 weeks, three times a week. In all groups the quadriceps force was improved by the exercise programs. The improvement in quadriceps force was greatest, both dynamically and statically, after isokinetic exercise.

THE SWEDISH NATIONAL KNEE ARTHROPLASTY PROJECT - A PROGRESS REPORT

M. Gruber, G. Bauer & A. Lindstrand
Lund

Since 1975, 824 cases have been reported so far to the central register. Nine per cent were post-traumatic, osteonecrosis etc., whereas the remainder were evenly divided between osteoarthritis and rheumatoid arthritis patients. The compartment sliding type of prosthesis has been the most frequently used, with the Marmor prosthesis being the most popular. Complications have been recorded in 10 per cent of the cases. Deep infection, as a late complication, has so far been recorded in only six cases, of which four occurred after implantation of a hinge prosthesis. The early mortality was 0.25 per cent.

ROENTGENOGRAPHY OF KNEE ENDOPROSTHESES

S. O. Ahlback & J. Rydberg
Stockholm

The radiograms of the patients involved in the national project are being reviewed centrally with classification of the preoperative roentgen

diagnosis. The basic concept is that engagement of both the lateral and medial compartments of the joint should be arthritis rather than arthrosis. It is necessary that gonarthrosis be classified according to localization of cartilage destruction and distribution of osteophytes. Also, a roentgenographical appearance of the types of knee prostheses is being prepared, which, in the future, will serve as a guide for radiologists.

TWENTY-FIVE YEARS EXPERIENCE OF ARTHROPLASTIES

B. Walldus
Stockholm

A personal experience of arthroplasties 1951 was presented. Based on experience with use of cement since 1953, it is suggested that endoprostheses should be designed to stay and to function without cement. Any foreign body will be surrounded by a fibrous tissue. An endoprosthesis must be mechanically arranged in order to permit a degree of elastic deformation in this tissue, without running the risk of loosening. Types of knee prostheses and the reasons for sequent modifications were described. A type has a built-in capacity for rotation.

RECONSTRUCTION OF THE MEDIAL TRANSVERSAL PATELLAR RETINACULUM IN CASES OF LATERAL TILTING PATELLA

F. Tidestrom
Linköping

The medial third of the patellar ligament together with a part of the tibial ligament is dissected from below up to a 45° downwardly inclined line on the middle of the patella. It is then turned medially, drawn below the end of the adductor magnus tendon and secured itself, pulling the patella medially. This procedure was applied in cases of laterally tilting patella in order to prevent sideways movement. In 11 patients, aged 15 to 52, this procedure was followed by improvement of the condition.

SYNOVIA - A CRYSTAL BALL FOR ORTHOPEDIC SURGEONS

P. H. Widmark
Malmö

Syn (like) - ovis (egg) - analysis in the polarizing microscope is now in fashion. However

na glucose content is also of interest. A value during the "normal" serum value will frequently unmask a latent or manifest diabetes mellitus. In postoperative hemarthrosis in phlebotic, gouty or rheumatoid joints there often is a high intra-articular pressure, low pO_2 , high pCO_2 level and a decreased pH, all of which changes are unfavorable for the metabolism of articular tissues. Such joints, therefore, should be drained and frequently aspirated.

DIAGNOSIS OF DEEP INFECTION AFTER TOTAL HIP REPLACEMENT

Carlsson, G. Josefsson & L. Lindberg
Gävle and Lund

The diagnosis of early infection following total hip replacement is usually simple but difficulties may be encountered in cases with symptoms arising months or years postoperatively. In such cases, signs and symptoms, simple laboratory methods and radiographic examinations are of little use for the diagnosis. The most prominent signs are pain on walking, located in the groin or thigh, rotational pain, elevated ESR and radiographic bone resorption. In doubtful cases, arthrography and, rarely, arthrography may be of use. For the definitive diagnosis, aerobic and anaerobic cultures of deep biopsies are required. It is recommended to withdraw antibiotics several weeks prior to biopsy.

MATCOGENOUS INFECTION

The incidence of hematogenous infection in total hip arthroplasties has been calculated to be 0.3 per cent. The onset of infection is rapid and signs and symptoms similar to other forms of septic arthritis. In 18 cases described in the literature and five cases of our own, infection started 3-66 months (mean 26) after operation. The causative microbes were *staphylococcus aureus*, *E. coli*, *proteus mirabilis*, *beta streptococcus* and *pneumococcus*. In almost all cases, removal of the prosthesis became necessary and four patients died. At present, a thorough debridement, followed by irrigation and drainage, to be the treatment of choice.

COBALT ALLERGY - A CAUSE OF ENDOPROSTHESIS LOOSENING

A. Heyer, U. James, H. Kogler & K. Undeland
Uddevalla and Örebro

Seven cases are presented in whom cobalt allergy is suspected as a factor contributing to poor results of knee endoprosthesis. In four of the cases, the prosthesis had to be removed. There were negative cultures, at least two, anaerobic and aerobic, in all cases, and four had a skin rash in the knee region. Four cases had cutaneous tests, positive for cobalt allergy. All seven cases were metal to metal endoprostheses (Waldius and Guepar). It is suggested that metal to metal articulations be avoided, and that epicutaneous tests for metal allergy be included in the pre-operative procedure.

BRACHYMESOPHALANGIA AND OSTEOCHONDRITIS DISSECANS

B. Lindén
Malmö

This is a condition which combines hypoplasia or even aplasia of the middle phalanges of the hands and/or the toes with osteochondritis dissecans in the carpo-metacarpal joints. The syndrome was discovered in one patient, who presented with locking in a metacarpo-phalangeal joint. The family of this proband consisted of 27 individuals, 17 of whom were investigated. Ten of these had the syndrome, and out of the remaining 10, another 4 possibly had similar changes. The heredity is autosomally dominant. Those affected had no other malformations or clinical signs and the syndrome had rarely caused clinical symptoms.

THE EFFECT ON ARTICULAR CARTILAGE OF INTRA-ARTICULAR INJECTION OF OSMIUM TETRAOXIDE AND RADIO-GOLD IN EXPERIMENTAL ARTHRITIS

Å. Ahlberg, A. Henriksson, H. Telhag & F. Wollheim
Malmö

Antigen-induced arthritis was produced in 30 adult rabbits, using ovalbumin. After 4 weeks 10 rabbits received 0.3 ml 1 per cent Osmium tetroxide, 10 rabbits 100 μ Ci ^{198}Au intra-articularly and 10 served as controls. In addition, 10 rabbits without arthritis were treated with osmium and 10 with ^{198}Au . Light microscopy showed severe destruction of articular cartilage in the osmium-treated animals, worse than in the controls. On the other hand, the degree of destruc-

tion in the ^{199}Au -treated animals was less than in the controls and the osmium animals. In all the non-arthritis animals light microscopy was normal regardless of treatment. Autoradiograms (^3H -thymidine) showed injury to the cartilage in all groups

TENODESIS IN RECIDIVOUS ANKLE SPRAINS USING THE SHORT PERONEAL TENDON

L. Ottosson
Borås

Lateral ankle instability was treated with peroneal tendon tenodesis. Forty-two patients, operated in this manner, were followed up, on average, 5 years after surgery. Most of these patients had a distinct trauma in their history with instability, repeated sprains and, periodically, pain at rest. The procedure caused no complications and was followed by improvement in all but three of the patients. The most common persistent symptom was lateral swelling in 14 cases. Four patients were unable to do physical exercise after surgery. It was demonstrated that tenodesis, using the tendon in its normal position, has a good stabilizing effect on the ankle joint.

EXTIRPATION OF TUMORS LOCATED NEAR THE THORACIC CAGE

B. Stener & G. Markhede
Göteborg

A method is described by which the external thoracic fascia, the external intercostal muscles and the perosteum of the external surface of the ribs can be included in the specimen as a continuous wall of healthy tissue on the deep side of the tumor. This technique has been used in 11 patients, nine of whom had undergone one or more inadequate operations earlier. Eight patients had malignant tumors, three an extra-abdominal desmoid. In one of the latter patients, in whom a recurrent tumor was adherent to the rib perosteum, the method was unsuitable. In the other patients, the method appears to have been adequate for local control of the tumor.

WHEN SHOULD OS CALCIS FRACTURES BE OPERATED ON?

O. Thoren
Vanersborg

In the past, it has been demonstrated that cases with severe displacement and with a Böhler angle of 0° or less are more successfully treated sur-

gically than conservatively. Using 32 suitable cases were operated on 2 days after the injury. The operation was by a lateral incision, the posterior aspect of the joint being elevated and supported for support. The previous concept of indications for surgery was supported by the results of this series.

WORKING CAPACITY FOLLOWING MCMURRAY OSTEOTOMY

M. Yllö
Skövde

Thirty-seven patients, 27 men and 10 women, with coxarthrosis, in many instances were operated on with a McMurray. The follow-up was at least 2 years. The age range for women was 24-58, and for men 36-64. It was demonstrated that 25 patients were able to do heavy work whereas 12 were doing light work. Twenty-seven went back to work after the operation. Seventeen were able to do the same work after operation as before whereas 10 had to change to a lighter job. Ten patients did not go back to work.

BONE MINERAL IN BALLET DANCERS

S. Andersson
Malmö

In professional ballet dancers, the bone mineral content was measured in the cancellous bone at the proximal end of the tibia. The value was significantly increased as compared with a ballet control population, the mineral content being, in many instances, so great that it was above the range of normative data. As the dancers were also given of a severe post-traumatic osteopenia, following a minor foot injury to a ballet dancer.

LOSS OF BONE MINERAL AFTER TIBIAL SHAFT FRACTURE

S. Andersson
Malmö

After a tibia shaft fracture the bone mineral content of the distal end of the tibia was decreased. The average loss was about 6% within the first year. There was no recovery of bone mineral but the original level was never attained. There was no difference in this regard between 13 patients treated with long leg plaster cast and crutches and 14 treated with a functional plaster cast.

ht bearing with a free knee joint and no
ort.

IS OF BONE MINERAL AFTER AMENTOUS KNEE INJURIES

Anderson
mo

he bone mineral content in the proximal end
of the tibia was measured in patients with clinical
signs of ligamentous knee injuries from the day of
injury and over a period of 1 year. There was
a 7 per cent loss of bone mineral in those
patients who were treated with an ace-bandage
and mobilized as soon as possible, and 14 per
cent in patients operated on with repair of the
ligaments and postoperative plaster cast for 6
weeks. No signs of restoration of the lost bone
mineral were noticed in any of the groups.

ORTHOPAEDIC HEALTH SURVEY OF YEAR-OLDS IN STOCKHOLM

Spangfort
Lundberg

About 5 000 69-year-old men and women,
inhabitants of the city of Stockholm, who had not
been admitted to institutions, were surveyed with
regard to orthopaedic conditions. Sixty per cent of
the women and 50 per cent of the men had sub-
jective symptoms from spine or joints, of which
one-fifth were classified as severe. However, only
3 per cent had an obvious orthopaedic condition
warranting referral for orthopaedic treatment.
Areas 6-7 per cent had symptoms which
probably could be managed in a general practice.
The survey did not support the concept of a large
"latent" need for orthopaedic services in this
section of the population, nor that routine health
surveys of the elderly by orthopaedic specialists
would be justified.

TECHNICAL FAILURES WITH THE ENDER NAILING PROCEDURE

Hult ■ M Nilsson
Stockholm

Technical difficulties were encountered in 62
out of 920 cases. The nails slipped in 31 cases in
the distal third of the bone, owing to compression of the fracture causing
the nails to slip and interfere with the knee
extension, and, in 15, because of poor fixation with
dislocation of the fracture. All 31 cases were re-
operated on. In 6, the nails were removed after the
fracture was healed whereas slipping in conjunc-
tion with fracture dislocation could not be

successfully re-operated using Ender nails.
Perforation of nails into the acetabulum occurred
in 19 cases but caused little discomfort to the
patients. In nine cases, nails were displaced
outside the femoral neck and head. All fractures,
including those with technical failures, healed
satisfactorily.

FRACTURE ORTHOSES

D Moxer
Borås

A fracture orthosis should fulfil the criteria of
being available to supply a fracture at short notice
and without time-consuming shop work.
Thermoplast can be moulded on the leg. The
orthosis is cut longitudinally leaving a gap of 1 cm
and then attached to the limb under pressure.
Also, fixtures are attached with thermoplast.
These orthoses are best suited for thigh and
below-knee fixation. The main advantages are low
weight, easy handling, radio-translucency,
immediate weight-bearing and control of compres-
sion. In a series of 30 patients, the opinion of the
patients regarding this bandaging technique was
very positive.

THE TULIP PROSTHESES

O Henriksen, G Marich & B Persson
Karlskrona and Lund

In the tulip prosthesis a cushion filled with tiny
plastic balls is moulded onto the stump. The air is
evacuated by a pump from this "air splint", which
then serves as a semi-rigid provisional stump
support which may be inserted into a standard
adjustable early walking aid and secured with four
"petals" (hence the tulip). In a series of 13 below-
knee amputees aged 37-88 this method greatly
improved the results of early postoperative
walking exercise. Also the physiotherapists were
able to handle this phase of rehabilitation in-
dependently without involving the brace shop in
the individual cases.

ASPECTS OF SENSORY FEEDBACK FROM MOTORIZED PROSTHESES

P Herberts, L Korner & A Anani
Göteborg

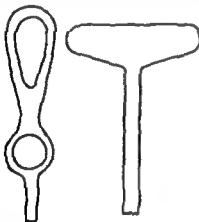
Afferent electrical nerve stimulation was carried
out, using a percutaneous method for intraneural
stimulation of nerves in the amputation stump of
below-elbow amputees and by sensory nerve
stimulation in non-amputees. It was found that
frequency or amplitude modulated stimulation

after a limited training could convey information on about five to six discrete levels with a rate of correct recognition of greater than 80 per cent and with an amount of transmitted information of 1.80–2.05 bits per symbol. These results have encouraged further work in order to develop a motorized prosthesis with this kind of feedback system.

ERGONOMICALLY IMPROVED RETRACTOR HANDLES

H Ekstrom & O Lindahl
Linköping

On the basis of ergonomic considerations, the traditional retractor handle designed about 1890 has been replaced by a new handle (Figure). It could be demonstrated by experiments and practical tests that the new handle offers a considerable improvement by distributing the pressure of the tool more evenly and reducing the muscle force needed to maintain a constant traction at a level which is more comfortable for the surgical assistant.



THE SCAPULO-COSTAL SYNDROME

L. Blomberg
Borås

Tenderness of the superior angulus of the scapula, radiating pain to the neck and sometimes to the arm, and dysfunction of the levator scapula muscle and to some extent the rhomboids, are characteristics of the scapulo-costal syndrome. Four patients were described. The etiology seemed in all cases to be a sprain of the arm and shoulder. In one case with very severe pain after

SYMPOSIUM – OCCUPATIONAL ORTHOPEDICS

INTRODUCTION I

A Nachemson
Göteborg

The locomotor system is the most common of occupational disability with disorders of the back. Our knowledge relationship between working conditions in the back is incomplete. It is therefore to devote much more work in and take interest in occupational orthopedics.

INTRODUCTION II

G Danielsson

The National Board of Occupational Safety and Health, Stockholm

With the reform of July 1 1977 in the definition of occupational injury will be to include conditions not necessarily an accident. The problems involved in occupational orthopedic conditions will therefore be important in the future. Today department of occupational medicine are being established over the country and most of the health care are being covered. It is desirable to decentralize these activities. An objective of occupational medicine is to health care in general into closer connection with working conditions. Orthopedics will in respect, be one of the most important branches of medicine.

EXAMPLES OF INJURIES TO THE BACK

A Nachemson
Göteborg

Between blue collar and white collar workers there is no difference in the incidence of disorders of the back. The importance of psychosocial factors for low back incapacity is well documented. Working conditions, particularly jobs requiring lifting strength, stooping postures or demands for maximal physical effort, are of major importance in this context. With electromyography and pressure measurements it is possible to find optimum sitting working position in patients with severe back pain. Patients with chronic low back pain are dominantly affected by bending and twisting movements. However, in other many patients with back pain will not locomotor capacity comparable with normal.

It has been demonstrated that the compression of the nucleus pulposus is poorly compensated by

content of oxygen and glucose. In the line, between the nucleus and the annulus, ruptures may occur at an early stage of generative process. These changes may be pronounced if the disc is subjected to static of a long duration.

METHODS EMPLOYING ELECTROMYOGRAPHY FOR MECHANICAL STUDIES of deformations Göteborg, Göteborg

Muscular load presents the most common problem among Swedish workers, as far as work environment problems are concerned. Quantitative methods for studying physical work are needed, and EMG methods are of major potential interest in this regard. Static work is accompanied by changes in the spectral composition of the EMG, and the rate of decrease in muscle fiber conduction velocity. The quantitative interpretation of these changes is greatly facilitated by using intramuscular single wire electrodes for signal pick-up. This method is also applicable in field studies on the shop floor.

METHODS OF BACK LOAD MEASUREMENTS Göteborg, Göteborg

Very few objective methods for measuring forces on the body are currently available. Examples include recordings of intra-discal pressure and of intra-abdominal pressure. Monitoring of surface electric back muscle activity using surface or intramuscular electrodes is also useful. Quantitative electromyography has been applied

in studies of working postures in the laboratory as well as on the shop floor. The myoelectric signal amplitude is a predictor of muscle force, and the changes in the signal power spectrum parallel localized muscle fatigue. It has been demonstrated that the myoelectric activity and the intradiscal pressure of the lower back increase linearly with the load on the spine. The method of weight-lifting — back-lifting or leg-lifting — seems to be less important whereas the distance between the weight and the body is more important for the load on the back.

SHOULDER PAIN IN ARDUOUS INDUSTRIAL WORK P. Herberts Göteborg

Static work was studied by means of quantitative electromyography from muscles of the shoulder of welders in a ship-yard. The myoelectric spectral development indicated that localized muscle fatigue was common in prolonged overhead work, especially in the supraspinatus muscle. By means of clinical examination, soft tissue radiography and quantitative electromyography, the effect of this type of industrial work was evaluated in welders with typical shoulder pain. The study revealed that the older workers have a chronic tendinitis of the rotator cuff. The supraspinatus muscle was shown to be consistently fatigued during overhead welding. It is believed that this is an important factor in the aetiology of the shoulder pain.

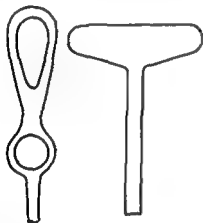
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JOBS EMPLOYING ROMYOGRAPHY FOR MECHANICAL STUDIES

verken, Göteborg

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MODES OF BACK LOAD REQUIREMENTS

longren
77

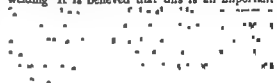
Objective methods for measuring forces on the body are currently available. Examples include recordings of intra-discal pressure and of abdominal pressure. Monitoring of intrinsic back muscle activity using surface or fine needle electrodes is also useful. Surface electromyography has been applied

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PROCEEDINGS OF THE FINNISH ORTHOPAEDIC ASSOCIATION

Kuopio, Finland, May 20, 1977

EDITOR A. ALHO

INCIDENCE OF THROMBOEMBOLISM IN ELECTIVE HIP SURGERY

O Suomalainen

University Central Hospital, Kuopio

Thromboembolic complications were analyzed in a series of 38 total hip replacements, 25 intertrochanteric osteotomies, and three endoprosthesis applications. Warfarin was used for prophylactic anticoagulation. Thrombosis was

simultaneously using xenon. Positive cases of thrombosis were also examined by contrast venography. A total of 23 (35 per cent) deep venous thromboses were diagnosed using 125 I fibrinogen; nine of these (14 per cent) were bilateral. Radionuclide venography using Tc^{99m} gave frequencies of 26 (39 per cent) and 7 (14 per cent), respectively. A clinical diagnosis of thrombosis was made in 16 cases (24 per cent). The same frequency, 24 per cent, was obtained by contrast venography. Ventilation perfusion lung scanning revealed nine lung emboli (14 per cent). Five patients had clinical symptoms of pulmonary embolism.

LUMBAR SPINAL STENOSIS

V Rehnberg

University Central Hospital, Kuopio

Between April 1974 and November 1976 a total of 29 patients were operated on for spinal stenosis at Kuopio University Central Hospital. This accounts for 13.9 per cent of all disc operations performed during that period. The average age of the patients was 47.8 years (40 to 66 years). Preoperatively, back and leg pain were the most common complaints, both occurring in about 90 per cent of the series. Nineteen patients (65.5 per cent) had cauda equina and intermittent claudication.

A positive Lasègue (SLR) sign was found in 26 patients (41.6 per cent). The most neurological disturbances found were loss of the Achilles reflex (12 patients) and loss of the power of the toe extensors (8 from hypaesthesia corresponding to dermatome S1 (13 patients in all). According to the findings five (17.2 per cent) of the patients considered to have congenital stenosis; stenosis in the rest was mainly degenerative origin.

The operation consisted of a deep laminectomy, usually performed on two levels. In no case was spinal fusion performed. The postoperative follow-up was 13.3 months. Results were excellent or good in 65.5 per cent of the patients.

TREATMENT OF TROCHANTERIC FRACTURES OF THE FEMUR BY THE ENDER METHOD

V Rehnberg & S Pellam

University Central Hospital, Kuopio

Intramedullary Ender nails have been used in the treatment of trochanteric fractures of the femur in Kuopio since March 1976. References to the first series of 27 patients treated by the Ender method. The mean age was 77 years. The duration of the operation was 47 minutes. Blood loss varied from minimal loss to 100 ml. One patient died postoperatively of myocardial infarction.

The fact that the distal ends of the nails beginning were not fixed with screws and most of the complications. In four cases or more of the nails had to be removed or they slid downwards. In one patient the non-union and in another wound infection case a reoperation had to be performed. A Jewett nail. Minor sliding of the nail of the pain at the site of insertion and a delayed healing of the fracture in a treated

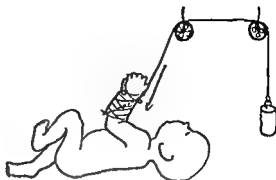
Another healed in a rotational malposi-

tion. This method has three advantages: it is technically difficult, it reduces operative stress to a minimum, and allows immediate weight-bearing.

NON-SURGICAL TREATMENT OF BRACHIAL PLEXUS Palsy WITH DYNAMIC TRACTION

by
J. Paediatric Surgery, University Central Hospital, Kuopio

Twenty-two of 23 newly born babies with brachial plexus palsy were treated with dynamic traction and functional physiotherapy (see Figure). Eleven (fifty percent) cases of C_5-C_6 spinal root involvement (Erb's palsy) recovered in 1-5 months (mean 2.5 months), a further four cases recovered in 6-12 months (mean 10 months). Two recovered after 18 months. Two recovered after 24 months. Two developed permanent handicaps, as did a further four cases of C_7-C_8 involvement. One severe case required surgery as primary treatment.



Dynamic traction effectively activates the paretic arm and this regimen is easy to carry out at home, too. As it gives evidence of the trend in recovery more rapidly than any other current method of treatment, it reveals resistant cases early enough to enable surgical correction. In all cases of brachial plexus palsy, dynamic traction treatment is indicated because the extent of involvement does not necessarily correlate with the speed and extent of recovery.

OSTEOGENETIC STIMULATION BY EXTERNALLY APPLIED DC CURRENT

ARSKI*, D DEMETRIADES† & A MACKENZIE†

*University of Waterloo, Mechanical Engineering Department, Waterloo Ontario, and
†Royal Children's Hospital, Montreal, Quebec, Canada

A new, simple, safe and noninvasive technique for the electrical stimulation of fracture healing is introduced. The safety and the simplicity of the technique makes it possible to apply it almost immediately to clinical experimentation. Electrodes were applied externally to the fractured site producing current across the limb. It was observed that the current density changes the volume of callus and affects the direction of the trabecular orientation. When the trabecular orientation is completely changed from longitudinal to transverse, the larger volume of callus does not compensate for the loss of strength as compared with the callus on the control bone.

Key words: osteogenic callus, bioelectricity, bone

Accepted 13 ix 77

It is a well established fact today that DC and electrical microcurrents have an effect on bone genesis. The phenomenon was first observed by Yasuda et al (1954), Iida et al (1956) and Noguchi (1957), later by many researchers in North America and Europe and similar results were reported by Bassett (1964 and 1975). It is also generally accepted that stimulating currents range between 5 μ A and 25 μ A, higher currents may have deleterious effects.

The mechanism of electrical stimulation still remains a matter of conjecture, however, several hypotheses attempting to describe mechanisms in the electrically stimulated tissue environment have been proposed. It is only reasonable to accept the fact that in the presence of ionic currents, various effects of electrolysis must be present (Pilla 1974). Thus most investigators have reported, on the basis of *in vitro* (Becker & Murray 1970) and *in vivo* (Noguchi 1957 and Friedenberget al 1960) studies, higher osteoblastic activity on

the cathode side and osteoclastic on the anode side. The ionic byproducts have also been observed in the tissue surrounding both the anode and the cathode. The puzzle which still remains unchallenged is cellular behaviour between the cathode and the anode. The conductivity in the soft and the hard tissue is predominantly ionic. Thus there are cations and anions moving through the tissue in the presence of an electrical current. Assuming that there is always a balance of positive and negative ions, the cellular environment will remain unchanged. However, there is a high probability that in the path of ions there exists selective adsorption of some ions and possible semiconductive properties of tissue (Digby 1966, 1974). The combination of the above parameters and differences in the ionic mobility would produce, according to Digby (1974), local changes in pH and thus affect precipitation of calcium salts which is highly dependent on pH. This would change the immediate cellular environment even far

removed from the electrodes. It is also reasonable to speculate that the change of the cell's environment would control its metabolic activity (Parsegian 1974).

Assuming that the above rationalization is true, the following two simple conclusions can be established

1. The direction of the microcurrent does not have to be across the fracture site or parallel to the long axis of a bone, the way it has been attempted by Yasuda et al (1954), Iida et al. (1956), Bassett et al (1964, 1975), Becker & Murray (1970, Kraus & Lechner (1972), Levy (1974), Haas (1963), etc.
2. The specified magnitude of the current in electrical stimulation is an insufficient parameter. It would be more desirable to know the current density in the stimulated region.

METHODS

On the basis of the above conclusions, a new technique of electrical stimulation was designed.

Electrodes were attached externally to the skin of the fractured limb using ECG gel for better coupling and the electric current density was estimated from the model illustrated in Figure 1.

The complexity of the model illustrates the difficulty of the task, especially since it was not the resistance of the tissue which was needed. In order to estimate current density, the resistivity of all elements must be known. Clearly it is not possible

to obtain this information, therefore experimental methods should be used. It is in mind that the current density would depend on the thickness of a limb and the proportion of various kinds of tissue in it.

MATERIALS

Three consecutive series of 12 white American rabbits weighing between 3 and 4 pounds were used. Prior to the actual experiment, the resistivity of various tissue components was measured *in vitro* and *in vivo*. An estimate of the magnitude of current to be applied across the limb of a rabbit which would represent approximately an equivalent of the 1-2 cm between implanted electrodes used in experiments of previous investigators. In order to verify estimates, an insulated stainless steel wire, 1 mm bare end, was implanted at the fracture site produced in the radius of the experimental rabbit. External electrodes made from stainless steel thumb tacks, having a contact area of 12 mm², were applied with ECG gel to both sides of the osteotomy. A 10-volt power supply producing 150 μ A was connected to the electrodes and the current output was monitored from the exposed wire at weekly intervals for 3 weeks. The current remained unchanged during the whole period. The result was disappointing since it was estimated that the current would diminish with progressive growth and calcification of the bone. However, the value of 150 μ A, resulting in a theoretical current density at the site of fracture of 123 μ A/cm², was assumed to be close to the purpose of the first experiment. The actual current density inside the limb still remained a mere conjecture.

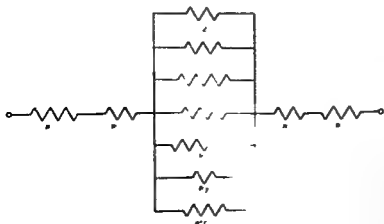


Figure 1. Electrical model of a fractured limb. R_1 and R_2 are the resistance of the skin, R_3 and R_4 are the respective resistance of muscle, connective tissue, ligaments, periosteum & hematoma etc.

RESULTS

Experiment 1

Bilateral osteotomies on the radius of twelve dogs were produced using a 0.05" thick flat wire. After a 1 day postoperative recovery period, electrodes were applied externally to the radius, one pair without an electric current and the other connected to a power supply. Electrodes were positioned in such a way that the current was directed through the ~~osteotomy~~ s.e. Animals were placed in restrainers and stimulated electrically with $1 \mu\text{A}/\text{cm}^2$ for 3 hours every day for 14 days. After 14 days, animals were sacrificed with an overdose of anesthetic and the bones were examined for callus formation at the control and experimental areas. Two weeks of healing appeared insufficient to form a fully calcified callus. Most specimens exhibited cartilaginous parts in the centre of the osteotomy separating the calcified callus. In six of the experimental bones and in two controls the ~~osteotomy~~ was completely bridged by fully formed callus. Since mechanical testing, with the exception of the latter eight specimens, did not produce any results, only the size of the formed callus was examined. The bones were separated at the osteotomy and photographs on the macro attachment of a callograph were taken, showing the cross-sectional areas of the formed callus. Upon analyzing the results, it was found that the cross-sectional area of the callus of the stimulated bones was 27 per cent larger than the control side.

Experiment 2

It was evident that the postoperative healing time was not sufficient to produce fully formed callus, therefore the second group of animals was stimulated with the same current density for 21 days.

All bones from the stimulated and control dogs had rigid unions with fully calcified callus. The ends of the radius were mounted in the resin for tensile tests and stored in the solution at 0°C. The results of the

tensile tests were completely opposite to the expected values. The tensile strength of the stimulated bones was much lower than on the control side and the callus was much thicker.

At this stage, it was postulated that the current density had been over-estimated and therefore the opposite adverse effect was obtained for the same reason as observed in the fully invasive techniques by Pilla (1974).

Experiment 3

The third group of animals was stimulated also for 21 days but the applied current was reduced to $50 \mu\text{A}$, resulting in a current density of $41 \mu\text{A}/\text{cm}^2$. This treatment produced stronger and less bulky callus on the stimulated side.

The results of mechanical testing for all three experiments are summarized in Table 1.

DISCUSSION

The interpretation of the results is reasonably simple. Experiments 1 and 2 indicated that the current density of $123 \mu\text{A}/\text{cm}^2$ definitely produced a much more bulky callus than on the control side. The strength of the callus however was lower on the stimulated side. The comparison of values for the Ultimate Tensile Strength improved the level of significance of difference to 0.39 indicating that the quality of callus was also poorer. The larger volume of callus on the stimulated side was not able to compensate for the reduction in strength. Reducing the current density to $41 \mu\text{A}/\text{cm}^2$ reversed the results. Although the level of significance of the load to fracture was poor, the quality of callus was better resulting in a significant improvement in strength (UTS) on the electrically stimulated side.

Based on the above observations, it is not possible for this pilot project to claim quantitative results. However, a general qualitative but also very significant observation can safely be made. The current density controls the strength, the amount and the porosity of the forming callus. Larger

Table 1 Results of mechanical testing

	Control bones	Stimulated bones	Percent of difference	Level of significance of difference
<i>Experiment 1</i>				
Av cross-sectional area ($\text{m}^2 \times 10^{-6}$)	15.68	19.98	+27	0.11
<i>Experiment 2</i>				
Av maximum load to fracture (N)	158.50	142.79	-10	0.43
Av cross-sectional area ($\text{m}^2 \times 10^{-6}$)	29.95	33.54	+12	0.09
Av UTS (MPa)	5.56	4.45	-20	0.39
<i>Experiment 3</i>				
Av maximum load to fracture (N)	180.84	185.56	+3	0.81
Av cross sectional area ($\text{m}^2 \times 10^{-6}$)	37.2	34.3	-8	0.34
Av UTS (MPa)	4.64	5.26	+13	0.5*

* *t* test for nonindependent samples.

current densities produce larger amounts of callus with higher porosity and poor strength.

In order to get one step closer to the explanation of this phenomena, the morphology of the formed callus was examined. The fractured ends of the bones were treated with Hydrazine (95 per cent) immersed in the bath of an ultrasonic cleaner. This treatment removed the organic phase, cleaned the remaining debris and left only fully calcified trabeculae. Control and stimulated callus were examined under the scanning electron microscope for the porosity and morphological formation of trabeculae.

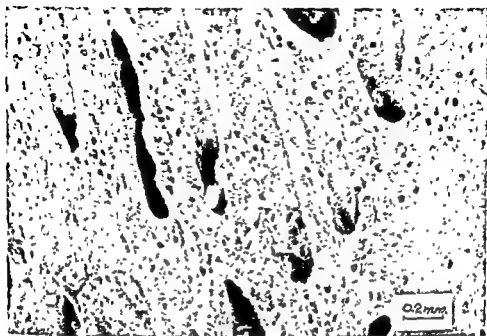
Figures 2a and 2b show the typical formation of trabeculae in the callus of the control bones in the three experiments. Figure 2a is the transverse view and Figure 2b is the longitudinal view of the same callus. Both photomicrographs show a preferred orientation of trabeculae parallel to the long axis of the radius. Figure 3 shows a side view of a callus electrically stimulated for 2 weeks with the current of $12.3 \mu\text{A}/\text{cm}^2$. The arrangement of trabeculae is longitudinal away from the fractured surface, but right at the fractured site it changes to the transverse orientation corresponding to the direction of

the current flow through the bone. Figure 4 is a side view of the callus on the fractured side stimulated with the current of $41 \mu\text{A}/\text{cm}^2$. Most of the callus has a longitudinal orientation of trabeculae with exception of occasional protrusions of distinctly transverse trabecular ones.

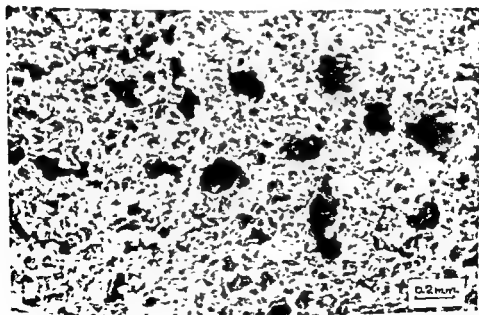
Conclusions

The fact that osteogenesis is stimulated by DC current has been documented before. This research may indicate that local osteogenesis depends on the local current density and that it is dependent on the resistance of the materials through which the current flows. The dramatic illustration of this fact is shown in Figure 4. It may be speculated that the large lumps of callus on otherwise smooth bone were the areas of higher current density, resulting in a large amount of deposit on the bone. The comparative results of the cross-sectional area of control and stimulated bones in Experiments 1 and 2 show that the electric current produces much more callus.

The growth of callus in the electrically stimulated rat radius was studied by Yasuda (1974). The remarkable observation



(a)



(b)

Figure 2. Transverse (a) and longitudinal (b) view of callus on the control side

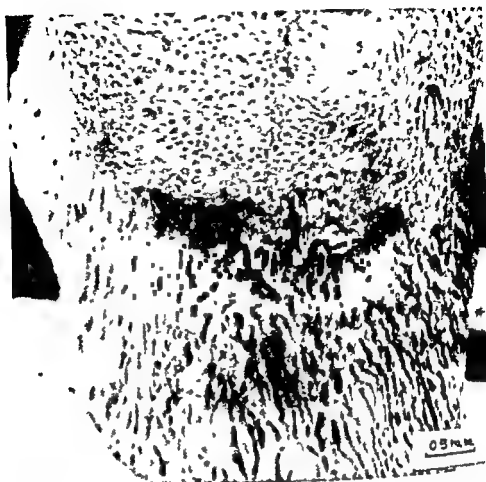


Figure 3 Side view of a callus electrically stimulated for 2 weeks with the 'current density' of 1.1 A/cm^2

this investigation is the effect of current on the directionality of trabecular formation. It appears that the electrical potential pre-determines the orientation of forming trabeculae in callus. In the normal healing process of bone there exists an electrical potential between the fractured ends which presumably controls the orientation of callus. Such a control results in the orientation of callus parallel to the long axis of the bone, which is observed in Figures 2a and 2b. When a higher potential, resulting in a higher current density, is applied across the fracture site as in Experiments 1 and 2, the trabecular orientation on the fracture side, where the conductivity through the haematoma was high, is perpendicular to the long axis of the

bone as though this were an overriding factor on the natural currents between fracture ends. Figure 4 shows the effect of electrical potentials. The trabecular orientation is found to change according to the localized current density. The path of the high current density presumably found a low resistance through parts of the haematoma, formed there trabeculae oriented at right angles to the long axis of the callus. The localized higher current still has not produced any other biological conditions except for the change in the trabecular orientation. Thus it is concluded that a theoretical current density of $40 \text{ } \mu\text{A/cm}^2$ is quite safe and the techniques have immediate clinical applications.

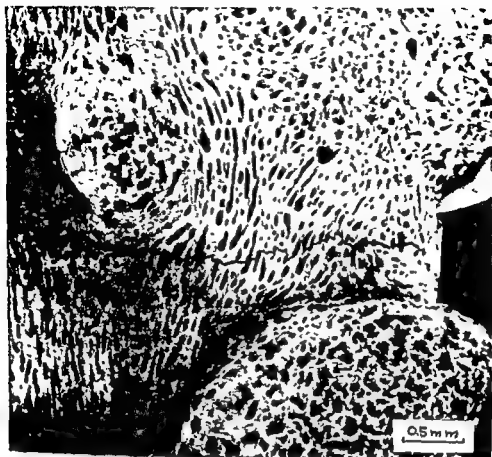


Fig. 4 Side view of a callus electrically stimulated for 3 weeks with the 'current density' of $41 \mu\text{A}/\text{cm}^2$

ACKNOWLEDGEMENTS

This research has been funded by the MRC grant from Montreal Children's Hospital.

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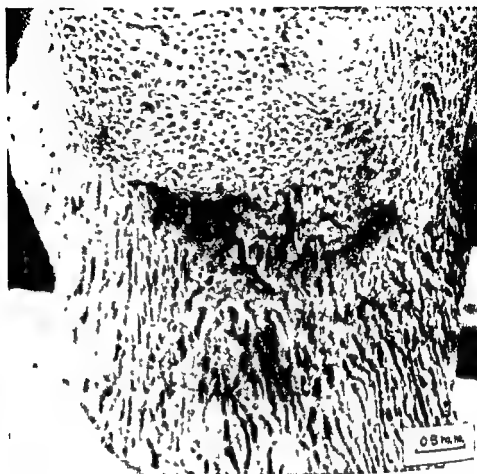


Figure 3 Side view of a callus electrically stimulated for 2 weeks with the "current density" of 120 $\mu\text{A}/\text{cm}^2$

this investigation is the effect of current on the directionality of trabecular formation. It appears that the electrical potential pre-determines the orientation of forming trabeculae in callus. In the normal healing process of bone there exists an electrical potential between the fractured ends which presumably controls the orientation of callus. Such a control results in the orientation of callus parallel to the long axis of the bone, which is observed in Figures 2a and 2b. When a higher potential, resulting in a higher current density, is applied across the fracture site as in Experiments 1 and 2, the trabecular orientation on the fracture side, where the conductivity through the haematoma was high, is perpendicular to the long axis of the

bone as though this were an overriding factor on the natural currents between fractured ends. Figure 4 shows the effect of potentials. The trabecular orientation to change according to the localized current density. The path of the high current, presumably found a low resistivity in parts of the haematoma, formed channels of trabeculae oriented at right angles to the long axis of the callus. The localized higher density of current still has not produced any biological conditions except for the change in the trabecular orientation. Thus, it appears that a theoretical current density of $40 \mu\text{A}/\text{cm}^2$ is quite safe and the technique has immediate clinical applications.

THE HEALING OF CARTILAGE INJURIES UNDER THE INFLUENCE OF JOINT IMMOBILIZATION AND REPEATED HYALURONIC ACID INJECTIONS

Experimental Study

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In an experimental animal model the influence of intraarticularly injected high-molecular hyaluronic acid on the healing of superficial and deep lesions of the articular cartilage in freely mobile and immobilized joints was investigated. In the right knee joint in 42 adult rabbits two intracartilaginous lesions were produced in one of the femoral condyles and an osteochondral lesion in the other. In half of the animals the injured knee joint was

graphically and the water content of the articular cartilage was determined. The intracartilaginous lesions remained unchanged in all knee joints. The wound margins of the osteochondral lesions showed better closure in the immobilized animals. As a rule the osteochondral lesion healed with fibrous connective tissue. In a few joints, however, hyaline cartilage, with production of chondroitin sulphate, developed during healing of the osteochondral lesion. In the vicinity of the joint surface this tissue was transformed into fibrocartilage. Immobilization of the joint invariably led to pannus formation. The hyaluronic acid injections appeared to have no effect either positive or negative, on the healing of intracartilaginous and osteochondral joint lesions. In mobile joints, however, these injections prevented a reduction of the water content of the articular cartilage, which was regarded as favourable.

Key words: articular cartilage, experimental injury, immobilization, hyaluronic acid.

Accepted 23 ix. 77

It is usually considered that osteochondral joint lesions heal by invasion of connective tissue into the cartilage defect from the subchondral bone, with subsequent development into fibrocartilage (Bennet et al 1932, Bennet & Bauer 1935, Campbell 1969, Lemperg & Hjertquist 1971, Puhl et al 1973).

Sometimes metaplasia to hyaline cartilage has been observed (De Palma et al 1966, Mitchell & Shepard 1976), although this cartilage gradually shows a greater resemblance to fibrocartilage (Lemperg et al 1971, Mitchell & Shepard 1976). It has also been found that immobilization of a joint in which an

experimental osteochondral lesion has been produced results in growth of richly vascular connective tissue—pannus—over the articular cartilage from the subchondral bone, causing cartilage destruction (Wigren & Olerud 1971, 1973, Wigren 1975). Intracartilaginous lesions produced experimentally have not given rise to osteoarthritis and have not healed even after long periods of observation (Thompson 1974, 1975). It has been claimed that intraarticular injections of high-molecular hyaluronic acid promote the healing of cartilage lesions (Balazs 1974), and very good results in treatment of traumatic arthritis in race-horses has recently been reported (Åsheim & Lindblad 1976). In a previous study this substance, when injected in high doses, to some extent prevented articular cartilage degeneration caused by immobilization (Wigren et al 1975). The aim of the present investigation was to examine, in a larger material of adult rabbit knee joints, the effect of high molecular hyaluronic acid on the healing of superficial and deep experimental cartilage lesions treated with and without immobilization of the joint.

MATERIAL AND METHODS

The study was performed on 42 adult rabbits of the Belgian Giant strain 2–3 years old and weighing 3.5–6 kg. All rabbits were operated on under general barbiturate anaesthesia. The right knee joint was exposed through a lateral parapatellar incision. Using an oscillating saw a 200 µm wide osteochondral lesion was produced longitudinally

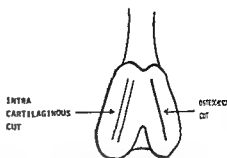


Figure 1 Schematic drawing of the location of experimental injuries on the femoral condyle.

on the medial femoral condyle and with a saw, two parallel intracartilaginous incisions were made on the lateral femoral condyle. A plaster cast was used. Twenty-one of the rabbits were immobilized with the knee joint in a vertical position in a plaster cast applied from the hip to the tip of the paw, while the other 21 rabbits were allowed to move the knee joint freely. A plaster cast was left in the plaster over the medial side of the knee joint for intraarticular injections. In 10 animals the left knee joint was left intact as control. Once a week starting 3–6 days after operation, 10 freely mobile and 10 immobilized knee joints were injected with 0.1 ml of high molecular hyaluronic acid (Sodium hyaluronate concentration 10 mg/ml, molecular weight 2 × 10⁶, Pharmacia AB) while the other injured knee joints were left untreated (Table 1). The treatment was continued for a total of 8 weeks, during which the animals were allowed to move about freely in their cages. Within 1–2 weeks after the last injection (i.e. 2–2.5 months after operation, India Ink (Gunter-Wagner Pelikan ink in isotonic saline solution) was infused under general anaesthesia through a cannula inserted in the abdominal wall.

Table 1 Macroscopic state of joint 2–2.5 months after osteochondral injury (The number of hyaluronic acid injected joints is shown in the table)

	Mobile joint n = 21		Immobilized joint n = 21	
	Inj with hyaluronic acid n = 10	Not inj n = 11	Inj with hyaluronic acid n = 10	Not inj n = 11
Vascular pannus over articular surface	1	3	8	2
Intraarticular adhesions	0	0	2	1

ording to the method described by Olcrud & lth (1963). The animal died during this infusion, ich was continued under positive pressure until 1-200 ml of the solution had been given. The e joint was then opened and carefully examined h respect to any signs of infection or injection ics. Specimens were taken from the medial and al femoral condyles for histological, histo- mical and microangiographic examination. ing a scalpel 20-40 mg of cartilage was taken m the femoral part of the femoro-patellar joint analysis of its water content (Figure 2) cimens for light microscopy and histochemical mation were fixed in 10 per cent neutral malin, decalcified in a mixture of sodium citrate l form a and not embedded in a matrix. A figure

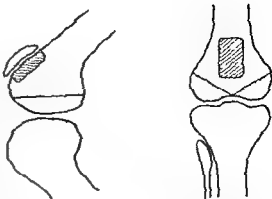


Figure 2 Schematic drawing of the sites on the femoral condyles from which the specimens were taken. Dotted areas: Specimens for histology, histochemistry and microangiography. Hatched area: Specimen for determination of water content.

4 MgCl₂ (Stockwell & Scott 1965) for fusion of the occurrence of chondroitin sulfate. Parts of the condyles were sawn into thin thick slices and treated by the Spalteholz method (1914) for microangiography. For estimation of the water content of cartilage samples, these were placed in weighed plastic bags which were then reweighed, and freeze-dried at a stable weight in an automatic freeze-dryer (Lyobold Herxius GT 4). They were then weighed on a balance (Mettler H 20 T) with a precision of 0.1 mg.

RESULTS

Microscopic observations

the arthrotomy which completed the experiment 2-2.5 months after the operation, in the superficial and the deep cartilage lesions were visible in all injured joints. No signs of intraarticular injection injuries or reaction were seen. In both immobilized and mobile hyaluronic-acid-treated knee joints the synovial fluid was normal in appearance and amount. In some of the mobile joints the tissue had formed in the osteochondral lesion a strikingly light, i.e. poorly vascularized, vascular pannus over the surface arising from the osteochondral lesion or the margin of the articular surface, was seen in 4 of 21 mobile joints and in 13 of 21 immobilized joints. This difference is statistically significant ($P < 0.01$). Of the four mobile joints with pannus, one had been treated with

hyaluronic acid, while in the 13 immobilized joints with pannus 8 had received this treatment (Table 1). Intraarticular adhesions were observed in a further three immobilized injured knee joints. Two of these had been treated with hyaluronic acid. Vascular pannus and/or intraarticular adhesions were thus found macroscopically in 4 out of 21 mobile joints and in 16 out of 21 immobilized joints. This difference is statistically significant ($P < 0.001$).

Histology and histochemistry

The intracartilaginous lesion. At examination of serial-sectioned specimens stained with haematoxylin-eosin and van Gieson's stain, all intracartilaginous lesions were found to be still open, with no healing reaction (Figure 3). No difference between the groups was seen in this respect. In no case did the scalpel incisions penetrate into the subchondral bone. The hyaline cartilage immediately bordering on the incision had a normal histological appearance and showed no reaction to the injury (Figure 3).

The osteochondral lesion in mobile knee joints. The wound margins had closed well in six



Figure 3 Open intracartilaginous lesion after 24 months. The absence of a healing reaction is illustrated. Haematoxylin-eosin $\times 100$.



Figure 4 Fibrous connective tissue fills deeper parts of this osteochondral lesion. The superficial part remains open. The joint was treated with hyaluronic acid. Haematoxylin-eosin $\times 63$.

untreated joints and in four joints treated with hyaluronic acid (Table 2). This difference is not statistically significant. In the remaining injured joints the osteochondral wound was still more or less open to the cartilage surface.

In most cases a vascularized fibrous

connective tissue had formed in the osteochondral wound cavity during the healing process (Figure 4). In two joints each from the hyaluronic-acid-treated and the untreated group the newly formed tissue resembled hyaline cartilage, being avascular and

Table 2 Status of the osteochondral wound 2-2.5 months after the lesion

	Mobile knee joints		Immobilized knee joints	
	Open wound	Closed wound	Open wound	Closed wound
Injected with hyaluronic acid	3	4	3	7
Not injected with hyaluronic acid	5	6	3	8

se fibrous components. In occasional s the basal part of the cartilage defect was l with bone tissue.

he blood vessels of the newly formed us tissue communicated with vessels in subchondral bone. In the deeper part of the n the collagen fibres ran upwards from the chondral bone towards the surface of the ilage, while in the superficial regions the s were mostly parallel with the articular ace. A moderate number of spindle-shaped cytes were seen in the fibrous tissue. The ecellular substance did not stain with an Blue.

1 three lesions from either group, large oval round chondrocytes were observed, ounded by a territorial zone which stained ngly with Alcian Blue in the presence of M but not 0.9M $MgCl_2$, indicating uction of chondroitin sulphate. The ndrocytes formed hyaline cartilage, mainly he basal part of the lesion. In one case this

hyaline cartilage contained cluster formations, and a proliferation of the tissue, which was undergoing transformation to fibrocartilage, formed a mushroom-like structure over the articular surface (Figure 5).

The amount of newly formed tissue varied considerably from knee joint to knee joint. In this respect there appeared to be no difference between the untreated and the hyaluronic-acid-treated groups.

In five joints the newly formed fibrous tissue was most extensive at the level of the calcification zone of the cartilage. In most joints the fibrous tissue decreased in amount in the superficial parts of the lesion and its surface lay at a lower level than the surrounding articular surface (Figure 4). In two cases from either group the newly formed tissue had grown beyond the level of the joint surface.

The articular cartilage around the osteochondral lesion was apparently unaffected, apart from occasional cluster formations in

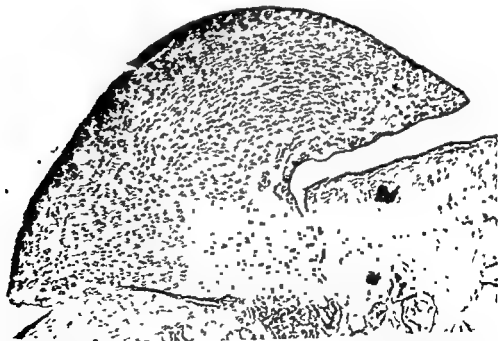


Figure 5 From this osteochondral lesion an unusually large amount of fibrocartilaginous tissue has grown to the joint surface. Some clusters are seen at the right hand margin of the proliferation. The joint was bled and treated with hyaluronic acid. van Geison $\times 40$.

Figure 6. Most of the wound cavity is occupied by red bone marrow. A thin bone bridge has formed between the bone marrow and the fibrous pannus on the joint surface of this immobilized joint. van Gieson $\times 63$.

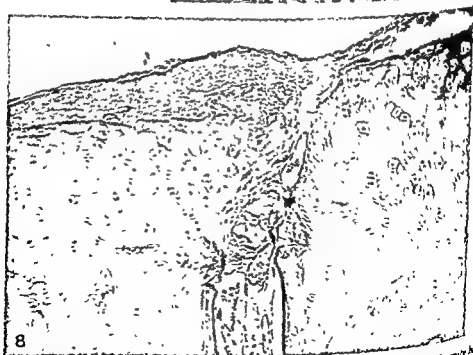
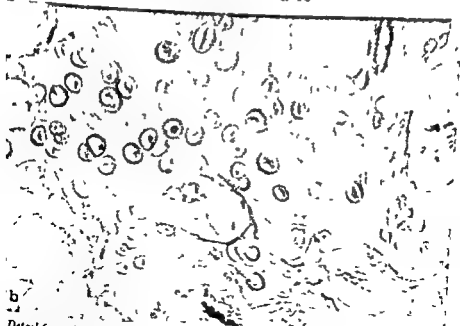


Figure 8. Only a small amount of reparative tissue is seen in this osteochondral wound cavity but prominent fibrous pannus covers the joint surface of the immobilized knee joint. van Gieson $\times 40$.

Figure 7a. Microphotograph of the healing of an osteochondral lesion with hyaline-like cartilage in the bottom of the lesion. Towards the surface the tissue has a more fibrous appearance Alcian Blue (0.4% $MgCl_2$) $\times 40$



Detail from the base of the wound in Figure 7a. Large chondrocytes are seen. Their matrix is stained with Alcian Blue at 0.4% $MgCl_2$, but not at 0.9%, indicating synthesis of chondroitin. The joint was immobilized but not treated with hyaluronic acid. Alcian Blue (0.4% $MgCl_2$)

one case. On the whole, the articular cartilage was histologically unchanged. Pannus growing over the articular surface was seen in only one of the joints.

The osteochondral lesion in immobilized knee joints No difference was found between hyaluronic-acid-treated and untreated knee joints with respect to closure of the wound margins (Table 2). The total number of closed lesions (15), on the other hand, was significantly greater than the number of open lesions (6) ($P < 0.05$). As in the mobile joints, the osteochondral lesion healed by formation of a vascularized fibrous tissue. In one non-injected joint, however, the greater part of the newly formed tissue was avascular and its basal portion resembled hyaline tissue, while the superficial portion showed characteristics of fibrocartilage. In seven joints the fibrous tissue was sparse and red subchondral bone marrow penetrated high up into the wound cavity (Figure 6). In 14 joints the fibrous tissue was separated from the red bone marrow by a bone bridge at the level of the calcification zone or surface layer of the cartilage (Figure 6). In these respects there was no difference between hyaluronic-acid treated and untreated

osteotomy gap, spreading over surface in the form of pannus (Figure 3, prominent in 10 of 11 untreated and in all of those injected with acid).

The articular cartilage close to the lesion exhibited no histological signs of osteoarthritis. However, the articular cartilage as a whole showed areas of degeneration under the fibrous pannus and vessels into the cartilage. The bone as a reaction to the difference between immobilized and non-immobilized injured knee, in respect to the development of statistically significant ($P < 0.001$).

Microangiography

Mobile knee joints The subchondral bone the osteochondral lesion was richly vascularized, with a growth of occasional vessels into the cartilage up to the tide-mark but not beyond it. The newly formed tissue in the gap between the articular surface and the tide-mark was very poorly vascularized. In specimens from the three joints a protrusion of tissue with vessels was observed above the level of the articular surface but no vascular invasion into this tissue (Figure 9). No growth of vascular pannus over the lesion was observed.

Immobilized knee joints From a vascularized tissue in the subchondral bone an abundance of blood vessels grew out from the lesion to the articular surface outwards over the surface of the cartilage (Figure 10). No difference was observed between hyaluronic-acid treated and untreated joints. Invasion of blood vessels into the cartilage through the tide-mark was observed in specimens from several joints.

Determination of the water content

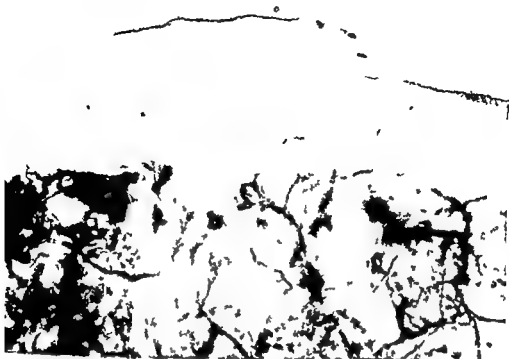
Mobile knee joints Owing to technical mishaps specimens for water content determination were only obtained from

In the newly formed fibrous tissue a moderate number of spindle-shaped fibrocytes were seen, and superficially the collagen fibres ran parallel to the articular surface. The intercellular substance did not stain with Alcian Blue.

In one joint from either group a moderate number of large oval or round chondrocytes were observed in the basal part of the lesion. Their matrices stained strongly with Alcian Blue at the lower of the two electrolyte concentrations used, indicating production of chondroitin sulphate (Figure 7a, b).

As in the mobile group the amount of newly formed tissue showed great individual variation and the two sub groups did not differ in this respect.

It was difficult to evaluate the level to which the newly formed tissue had reached as an outgrowth of connective tissue from the



9 Microangiogram showing the absence of blood vessels in the articular cartilage and in the reticular tissue which is also seen in Figure 5 Spalteholz $\times 63$



10 Microangiogram showing an abundant growth of blood vessels from the lesion and out over the surface Immobilized joint Spalteholz $\times 63$

21 joints. The results are given in Table 3. In the group not treated with hyaluronic acid the water content of the articular cartilage was significantly lower in the injured joints ($P < 0.01$) than in the intact joints of the same animals. In the hyaluronic-acid-treated group there was no significant decrease in this water content in the injured joint. Thus there was a significant difference between the water content of the articular cartilage in injured joints treated with repeated injections of hyaluronic acid and injured joints not injected with this substance ($P < 0.05$).

Immobilized knee joints. Specimens were obtained from all joints. The results are given in Table 4. Neither untreated nor hyaluronic-acid-treated knee joints showed any significant change in the water content of the articular cartilage.

DISCUSSION

The treatment of intraarticular injuries is a constantly recurrent problem in orthopaedics.

The question of whether or not osteochondral and intracartilaginous lesions heal and restoration of hyaline cartilage and degenerative changes of the articular cartilage develop, are of great importance. Immobilization of an injured joint which is necessary, may give rise to "arthritis" to the articular cartilage (Evans et al. 1960, Salter & Field 1960, Wigren & Olsson 1973, Finsterbush & Friedman 1973, Wik & Wik 1974). Hyaluronic acid has been reported to promote healing (Rehder & Balazs 1971). It has been found that repeated injections of this substance at short intervals act against degenerative changes resulting from experimental immobilization (Wigren 1975). The osteochondral lesions produced in the present experiments healed and development of fibrous connective tissue in some cases fibrocartilage. This has been reported by Campbell (1964) and others. The white scar tissue was also observed by Mitchell & Mitchell (1976). They found that after 8 weeks

Table 3 The water content of the articular cartilage of adult rabbit femoral condyles 2-7 months after experimental injury to the cartilage. Freely mobile knee joint. The influence of repeated plantations of hyaluronic acid. The articular cartilage from the intact knee joint of each rabbit as individual control

Animal no	% Water			Animal no	% Water		
	Operation + hyal acid	Control knees	Water content in % of normal		Only operation	Control knees	Water content in % of normal
13	70.0	70.1	99.9	2	63.5	68.1	95.7
17	67.9	68.4	99.3	3	67.3	67.1	98.4
18	68.2	67.5	101.0	4	58.8	67.6	97.3
19	69.2	69.9	99.0	7	69.5	69.3	99.7
23	62.7	68.0	92.2	8	56.3	68.8	81.8
25	69.4	67.7	102.5	9	60.8	64.6	94.1
30	64.0	58.6	109.2	11	68.4	68.5	99.9
				12	57.4	67.1	85.6
				28	63.6	64.6	98.5
				29	61.6	66.3	91.4

$n=7$
mean = 100.4
SD = ± 5.1

95 per cent confidence interval = 95.8-105.1

95 per cent confidence interval

Table 1. Water content of articular cartilage in normal condyles 2-2.5 months after operation.

% Water			Animal no	% Water		
Operation + hyal. acid	Control knees	Water content in % of normal		Only operation	Control knees	Water content in % of normal
72.3	71.5	101.0	1	66.7	67.1	99.3
63.7	68.7	92.7	3	63.5	68.4	92.9
66.1	66.2	99.8	4	68.3	68.3	99.9
69.0	68.3	101.0	6	68.5	68.4	100.2
72.4	69.0	105.0	9	62.2	71.5	87.0
72.2	71.1	101.5				
73.8	73.3	100.7	15	68.5	71.0	96.5
70.1	70.1	100.1	18	72.1	69.8	103.2
70.6	72.8	97.0	21	75.2	73.6	102.0
68.2	68.7	99.2	22	70.1	68.9	101.8
			24	69.0	70.6	97.8
			25	66.0	66.4	99.4
$n = 10$				$n = 11$		
mean = 99.8				mean = 98.2		
SD = ± 3.2				SD = ± 4.7		
95 per cent confidence interval = 97.5-102.1				95 per cent confidence interval = 95.0-101.3		

consisted of hyaline-like cartilage. Such was seen in only a few cases in our study. The relative duration of the observation may be of significance for the type of change found, but Lemperg & Hjertquist (1971) and Mitchell & Shepard (1976) observed that hyaline-like cartilage occurring early in the healing process of a cartilage lesion underwent further changes to dense fibrous tissue. In the present study the cartilage defect closed frequently in the immobilized than in the mobile joints and in all immobilized joints the defect was filled with scar tissue which formed a pannus. This reaction is a consequence of the immobilization (Evans et al 1960, Salter 1960, Wigren 1975). In the mobile joints an invasion into the defect by blood vessels was also observed, a clear indication of cartilage injury (Mankin 1971). No histological signs of osteoarthritis in the form of cluster formations or fibrillation were observed in the articular cartilage. The articular lesion did not seem to have developed into osteoarthritis, as has been claimed

by Puhl & Dustmann (1973, 1976). Farkas et al (1976) have denied such a development, however. It is widely agreed that normal mature articular cartilage does not show chondrocyte mitosis (Mankin 1963, 1974, Orto 1972). Our observation of an accumulation of chondroitin sulphate-producing chondrocytes in the basal regions of the osteochondral lesion corresponds with the findings of Mitchell & Shepard (1976) and might be explained by a dividing capacity of the chondrocytes which have been freed from the cartilage matrix during the production of the experimental lesion. Differentiation of immature cells to chondroitin sulphate-producing chondrocytes is another possibility - in this case induced by the trauma.

In a previous investigation (Wigren et al 1975) immobilization of a joint was found to cause a reduction of the water content of the articular cartilage. This finding is in agreement with the changes observed by Akesson et al (1974, 1975) in the connective tissue surrounding experimentally immobilized rabbit knee joints. In their study

21 joints. The results are given in Table 3. In the group not treated with hyaluronic acid the water content of the articular cartilage was significantly lower in the injured joints ($P < 0.01$) than in the intact joints of the same animals. In the hyaluronic-acid treated group there was no significant decrease in this water content in the injured joint. Thus there was a significant difference between the water content of the articular cartilage in injured joints treated with repeated injections of hyaluronic acid and injured joints not injected with this substance ($P < 0.05$).

Immobilised knee joints Specimens were obtained from all joints. The results are given in Table 4. Neither untreated nor hyaluronic-acid-treated knee joints showed any significant change in the water content of the articular cartilage.

DISCUSSION

The treatment of intraarticular injuries is a constantly recurrent problem in orthopaedics.

The question of whether or not osteochondral and intracartilaginous lesions heal, restoration of hyaline cartilage, degenerative changes of the develop, are of great importance. The treatment of an injured joint, which is necessary, may give rise to atrophy of the articular cartilage (Evans et al. 1960, Salter & Field 1960, Wigren & Olsson 1973, Finsterbush & Friedman 1974, & Wik 1974). High molecular hyaluronic acid injected into an experimentally injured joint has been reported to promote healing (Balazs 1971).

The use of this substance at short intervals to retard degenerative changes resulting from experimental immobilization (Wigren 1975). The osteochondral lesion in the present experiments healed, but the development of fibrous connective tissue in some cases fibrocartilage has been reported by Campbell (1969) and others. The white scar tissue was observed macroscopically in the superficial cartilage also been observed by Mitchell & Mitchell (1976). They found that after 8 weeks

Table 3 The water content of the articular cartilage of adult rabbit femoral condyles 2.5 months after experimental injury to the cartilage. Freely mobile knee joint. The influence of repeated intraarticular injections of hyaluronic acid. The articular cartilage from the intact knee joint of each rabbit was used as individual control.

% Water				% Water			
Animal no	Operation + hyal. acid	Control knees	Water content in % of normal	Animal no	Only operation	Control knees	Water content in % of normal
13	70.0	70.1	99.9	2	63.5	68.1	95.6
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18	68.2	67.5	101.0	4	58.8	67.6	86.9
19	69.2	69.9	99.0	7	69.5	69.7	99.7
23	62.7	68.0	92.2	8	56.3	68.8	81.8
25	69.4	67.7	102.5	9	60.8	64.6	94.1
30	64.0	58.6	109.2	11	68.4	66.5	102.8
				12	57.4	67.1	85.6
				28	63.6	64.6	98.5
				29	61.6	66.3	91.4

$n=7$
mean = 100.4
SD = ± 5.1

95 per cent confidence interval = 95.8-105.1

95 per cent confidence interval

The water content of the articular cartilage of adult rabbit femoral condyles 2-2.5 months after experimental injury to the cartilage. Immobilized knee joints. The influence of repeated intraarticular injections of hyaluronic acid. The articular cartilage from the intact knee joint of each rabbit served as an individual control

% Water			% Water			
Operation + hyal. acid	Control knees	Water content in % of normal	Animal no.	Only operation	Control knees	Water content in % of normal
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63.7	68.7	92.7	3	63.5	68.4	92.9
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69.0	68.3	101.0	6	68.5	68.4	100.2
72.4	69.0	105.0	9	62.2	71.5	87.0
72.2	71.1	101.5				
73.8	73.3	100.7	15	68.5	71.0	96.5
70.1	70.1	100.1	18	72.1	69.8	103.2
70.6	72.8	97.0	21	75.2	73.6	102.0
68.2	68.7	99.2	22	70.1	68.9	101.8
			24	69.0	70.6	97.8
			25	66.0	66.4	99.4
$n = 10$			$n = 11$			
mean = 99.8			mean = 98.2			
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95 per cent confidence interval = 97.5-102.1			95 per cent confidence interval = 95.0-101.3			

consisted of hyaline-like cartilage. Such tissue was seen in only a few cases in our study. The relative duration of the observation period may be of significance for the type of lesion observed.

The process of a cartilage lesion underwent secondary changes to dense fibrous tissue. In the present study the cartilage defect closed more frequently in the immobilized than in the mobile joints and in all immobilized joints the defect was filled with scar tissue more richly organized and grew over the articular surface as a pannus. This reaction is a consequence of the immobilization (Evans et al 1960, Salter 1960, Wigren 1975). In the immobilized joints an invasion into the defect by blood vessels was also observed, a indication of cartilage injury (Mankin et al 1971). No histological signs of osteoarthritis in the form of cluster formations or fibrillation were observed in the articular cartilage. The experimental lesion did not seem to have led to osteoarthritis, as has been claimed

by Puhl & Dustmann (1973, 1976). Farkas et al (1976) have denied such a development, however. It is widely agreed that normal mature articular cartilage does not show chondrocyte mitosis (Mankin 1963, 1974, Otte 1972). Our observation of an accumulation of chondroitin-sulphate-producing chondrocytes in the basal regions of the osteochondral lesion corresponds with the findings of Mitchell & Shepard (1976) and might be explained by a dividing capacity of the chondrocytes which have been freed from the cartilage matrix during the production of the experimental lesion. Differentiation of immature cells to chondroitin-sulphate-producing chondrocytes is another possibility—in this case induced by the trauma.

In a previous investigation (Wigren et al 1975) immobilization of a joint was found to cause a reduction of the water content of the articular cartilage. This finding is in agreement with the changes observed by Akesson et al (1974, 1975) in the connective tissue surrounding experimentally immobilized rabbit knee joints. In their study

21 joints. The results are given in Table 3. In the group not treated with hyaluronic acid the water content of the articular cartilage was significantly lower in the injured joints ($P < 0.01$) than in the intact joints of the same animals. In the hyaluronic-acid treated group there was no significant decrease in this water content in the injured joint. Thus there was a significant difference between the water content of the articular cartilage in injured joints treated with repeated injections of hyaluronic acid and injured joints not injected with this substance ($P < 0.05$).

Immobilized knee joints Specimens were obtained from all joints. The results are given in Table 4. Neither untreated nor hyaluronic-acid treated knee joints showed any significant change in the water content of the articular cartilage.

DISCUSSION

The treatment of intraarticular injuries is a constantly recurrent problem in orthopaedics.

The question of whether or not osteoarthritis and intracartilaginous lesions, restoration of hyaline cartilage, and degenerative changes of the articular surface develop are of great importance. In the treatment of an injured joint which is necessary, may give rise to irreversible changes in the articular cartilage (Evans et al. 1960; Salter & Field 1960; Wigren & Olsson 1973; Finsterbush & Friedman 1974; & Wik 1974). High molecular weight hyaluronic acid has been reported to promote healing (Balazs 1971). It has been found that in the presence of this substance at short intervals after surgery, degenerative changes result in experimental immobilization (Wik 1975). The osteochondral lesion produced in the present experiments had a tendency to development of fibrous connective tissue, in some cases fibrocartilage in the surface. This has been reported by Campbell (1964) and others. The white scar tissue observed macroscopically in the superficial cartilage has also been observed by Mitchell & Mitchell (1976). They found that after 6 weeks

Table 3 The water content of the articular cartilage of adult rabbit femoral condyles 2-2.5 months after experimental injury to the cartilage. Freely mobile knee joint. The influence of repeated intra-articular injections of hyaluronic acid. The articular cartilage from the intact knee joint of each rabbit as individual control

Animal no	% Water			Animal no	% Water		
	Operation + hyal acid	Control knees	Water content in % of normal		Only operation	Control knees	Water in % of normal
13	70.0	70.1	99.9	2	63.5	68.1	98.5
17	67.9	68.4	99.3	3	67.3	67.1	98.5
18	68.2	67.5	101.0	4	58.8	67.6	115.5
19	69.2	69.9	99.0	7	69.5	69.3	98.5
23	62.7	68.0	92.2	8	56.3	68.8	122.0
25	69.4	67.7	102.5	9	60.8	64.6	106.0
30	64.0	58.6	109.2	11	68.4	68.5	100.0
				12	57.4	67.1	117.0
				28	63.6	64.6	101.5
				29	61.6	66.3	107.5

$n=7$
mean—100.4
SD—+5.1

95 per cent confidence interval—95.8 105.1

95 per cent confidence interval

mean
SD
C.I.

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a reduced water content was associated with a decreased content of hyaluronic acid, a decreased amount of soluble collagen and a decreased content of hexosamine. These changes were also accompanied by impairment of biomechanical properties (Akeson et al 1975). In the present experiments injection of high-molecular hyaluronic acid counteracted a reduction of the water content of the articular cartilage in the experimentally injured, but mobile joint. How this effect is mediated is not clear (Wigren et al 1975). The synovial membrane plays some role (Wigren et al 1976). Adsorption of the greatly hydrophilic hyaluronic acid molecule to the surface of the articular cartilage may be another mechanism. In the immobilized joints the water content of the articular cartilage was not affected. This may have been due to technical difficulties in the sampling (Sokoloff & Hough 1975) or to concealment of a reduction in water content by richly vascular pannus over the cartilage surface, which might have accompanied and influenced the sample.

The intracartilaginous lesion had not healed, showed no reaction whatsoever after 2 months. This finding is in agreement with reports by Thompson (1974, 1975). No reaction of the subchondral bone beneath the lesion, as was described by Lemperg et al (1971), was seen. The articular cartilage around the lesion was completely unaffected, and showed no degenerative changes. The need for serial sectioning of specimens in evaluating intracartilaginous lesions must be emphasized, as apparent closure of the wound margins may give the impression that the lesion has healed. Injections of high-molecular hyaluronic acid appeared to have no effect on the intracartilaginous lesion.

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METASTATIC OSTEOMYELITIS FOLLOWING BCG VACCINATION

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An 8-year-old girl, who had been vaccinated with BCG without any regional reactions, developed osteomyelitis in the left calcaneus 7 years later. The process healed after surgical treatment and chemotherapy. Culture from the bone abscess gave growth of mycobacteria which could not be distinguished from BCG.

Key words: metastatic osteomyelitis, BCG vaccination

Accepted 14 XII 77

Metastatic osteomyelitis after BCG vaccination is a complication which has been reported only infrequently. Foucard & (1971) reported 13 cases, 9 of which were from Scandinavia. However, there has been much interest in this condition during recent years, particularly in Sweden and Finland, where it is taken into consideration in the discussions on vaccination policy. Only two such cases have been diagnosed previously in Denmark (Bang et al 1960, Mørkbak 1954) and the third is reported in this work.

CASE REPORT

An 8-year-old girl, previously healthy, was referred as an outpatient to the Orthopaedic Surgical Department on October 24, 1969, because of progressive pain in the left heel on weight-bearing and swelling around the lateral malleolus. Four months prior to the commencement of symptoms, the girl had been vaccinated with BCG at the Chest Clinic, without any known reactions.

Physical examination revealed a pronounced lump in the left leg, marked swelling behind the

lateral malleolus, and slight tenderness of the calcaneus. The sedimentation rate was 39.

X-ray examination of the left foot showed halisteresis and tomography a few centimetres below the surface of the joint. An incision was performed, and 3 ml pus and a fragment were evacuated from the calcaneus.

Microscopy of the pus (Ziehl-Neelsen, alcohol fast rods) showed growth of mycobacteria which could not be distinguished from BCG on the basis of morphology, biochemical tests and determination on guinea pig (Engbæk et al 1971).

Treatment was started with isoniazid (50 mg \times 3) and neotubercin (4 mg \times 3) after the operation. The bacteria isolated were highly sensitive to SM, PAS, INH, Rifampin and Ethambutol.

The patient was reoperated 4 months later because of continued secretion and a cavity filled with purulent bone tissue. Granulation tissue was found occupying the whole calcaneus. Microscopy revealed tuberculous granulation tissue with necrosis.

Ziehl-Neelsen staining showed no acid fast rods and PAS staining showed no bacteria. Culture gave no growth of acid fast rods.

During the anti-tuberculous treatment with streptomycin (total 16.5 g) and ethambutol



1 and 2 Tomography showing destructive process in the tuber calcanei extending to the surface of
4 (7 11 1969)



3 and 4 X-ray performed about 13 months later (same case as in Figures 1 and 2) showing
of the process in the left calcaneus (15 12 70)

LARSEN'S SYNDROME

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A girl with the characteristic abnormalities of Larsen's presented. A soft flabby consistence of the cartilaginous skeleton of the larynx and trachea was thought to be the cause of attacks of respiratory failure which suddenly caused her death at the age of 9 months. Microscopic revealed a considerably reduced number of elastic fibres in the larynx, trachea and bronchi. Closed reduction of the knee dislocation by skin traction was to be successful.

Key words: congenital malformations, knee dislocation.

Accepted 17 x 77

The first description of the disorder later known as Larsen's syndrome was given by Kayser (1935). He reported a case with congenital malformations including dislocation and facial deformities. There was also a family history of congenital deformities of the musculo-skeletal system. Larsen et al (1950) reported six unrelated patients with multiple joint dislocations, depressed nasal bridge and wide-spaced eyes. The joints most often affected were the knees, elbows and hips. Abnormalities of the foot, hand and spine, and cleft palate were also found.

Since this publication, some reports have appeared describing cases consistent with Larsen's syndrome (Curtis & Fisher 1970, Steel & Kohl 1972, Micheli et al 1976, Oki et al 1975). New findings have also been added to the clinical and pathologic-anatomic entity. Latta et al (1971) reported malformation of the larynx giving respiratory distress. Most authors have found a familial occurrence of the syndrome and Habermann et al (1976) reported four cases of Larsen's syndrome in three generations of one family and suggested a dominant mode of inheritance.

The purpose of the present paper is to report a case of Larsen's syndrome in which the patient suffered from attacks of respiratory failure. One such attack resulted in her death at 9 months of age. In this patient, closed reduction of the knee dislocation was attempted using skin traction.

CASE REPORT

The patient was a girl, 3 months of age when she was first seen at the hospital. She had a right knee dislocation and an old woman's appearance with an unusual shape of the older sister's joint. She had a depressed nasal bridge and hypertelorism. The father also had syndactylism of toes 4 and 5, and he had had a plastic operation for a flattened nose. The sister had short first metatarsal bones.

Shortly after birth it was noted that the girl had a dislocation of her right knee. Her face had a characteristic appearance with depressed nasal bridge and hypertelorism (Figure 1). The palate was high arched. Calcaneo-valgus deformity and short first metatarsal bones of both feet were found (Figure 2). Examination of the hips revealed a positive dislocation test on the left side. She



Figure 1 Depressed nasal bridge and ocular telorism in a 6 month-old girl with Larsen's syndrome



Figure 2 Short first metatarsal bone in Larsen's syndrome

a pectus excavatum deformity. Closed reduction of the dislocated knee was attempted but failed. The hip dislocation was treated by a Frejka cast and the foot deformity by corrective casts. A few days after birth, attacks of respiratory distress with cyanosis supervened. The attacks occurred during meals, and the patient had been fed through a stomach tube for some weeks. Laryngoscopy showed a soft, easily moving epiglottis and hypoplasia of the laryngeal cartilage. During the first 6 months of life, attacks became more infrequent, and when medical treatment of the knee dislocation failed, the respiratory failure was considered

terminal. Radiographs of the entire skeleton revealed an anterior dislocation of the right tibia on the femur, a dysplasia of the left acetabulum, an extra-articular centre of ossification of the calcaneus, a short first metatarsal bone of both feet. A general muscular wasting was found. Laboratory findings including chemical studies of serum and urine and electrocardiograms were normal. No muscle

biopsy was performed. Treatment with skin traction, the knee in semi flexion and countertraction applied on the distal thigh. After 3 weeks of traction radiographs showed that the dislocation was almost reduced to a normal position (Figure 3). However, sudden death supervened at this time due to an attack of respiratory failure.

Necropsy showed a soft, flabby consistence of the epiglottis and arytenoid cartilage. Trachea and larynx were partially collapsed. No signs of aspirated food or cardiac malformation were found. Macroscopy revealed a markedly reduced number of elastic fibres in the larynx, trachea and bronchi. Signs of an interstitial pneumonia were also found.

The right patella was connected to the femoral condyles by fibrous tissue occupying the entire suprapatellar pouch. Splitting of the infrapatellar tendon and the anterior part of the capsule led to reduction in the flexed position.

DISCUSSION

A girl having physical findings consistent with Larsen's syndrome is presented. Her father

and mother were normal. Treatment was started with skin traction, the



Figure 3 Anterior dislocation of the tibia (a) The knee almost reduced in skin traction (b)

and sister also had some deformities characteristic of this syndrome, and her mother had had two abortions. The family history could point to a dominant mode of inheritance with a wide variety in the penetrance of the disorder. Our case had a distinct maldevelopment of the cartilaginous skeleton of the larynx and trachea, verified at autopsy. Histological examinations revealed reduction of elastic fibres in these structures. This finding has not previously been reported in Larsen's syndrome.

At present Larsen's syndrome is a rather complex and not well defined entity. In Table 1 the abnormalities ever described in cases supposed to have this disorder are listed. Our

patient has added two abnormalities in the list, pectus excavatum and short 5th metatarsal bones.

Closed reduction of the knee was attempted at the local hospital shortly after birth but failed. At our hospital operative treatment was planned for when the respiratory problems were overcome. As a preoperative procedure skin traction was applied. Reduction was almost succeeded when the patient died. Oka et al (1976) also reported successful closed reduction of knee dislocation without skeletal traction. Most authors, however, advocate operative treatment and describe surgical procedures (Larsen et al 1950, Oka & Fisher 1970).

Table 1 Abnormalities described in patients with Larsen's syndrome (Taken from the reviewed literature) The most typical deformities are in *italics*

Abnormalities affecting the musculoskeletal system

cranial	<i>Muscular hypotonia</i>
facial	<i>Prominent forehead with depressed nasal bridge and widespaced eyes</i> <i>Maldeveloped maxilla. Supernumerary incisors.</i>
craniovertebral and spine	<i>Spina bifida. Abnormal segmentation. Fusion between atlas and skull. Flattened hypoplastic vertebrae. Pectus carinatum/excavatum.</i>
extremities	<i>Centres. Short metacarpals, sometimes with pseudoepiphyses on the bases of the 2nd and 3rd metacarpals.</i>
hips and knees	<i>Dislocated hip joints. Anterior dislocation of the knees</i> <i>Extra ossification centre of the calcaneus. Pes equinovarus/valgus. Short 1st metatarsals. Bifid cuboid bone. Subluxation in Lisfrance's joint</i>

Other manifestations

intellectual development	<i>Retarded in a few patients.</i>
cranial nervous system	<i>Ghosts in the cervical medulla (described in a patient with abnormality in the cervical column)</i>
respiratory tract, oral cavity	<i>Maldeveloped laryngeal cartilage and tracheal rings</i> <i>Cleft palate/uvula.</i>
gastro-urinary tract	<i>Undescended testicles</i>

Micheli et al. (1975) reported three cases of Larsen's syndrome with bone abnormalities of the cervical spine. In one of these cases spinal instability with damage to the spinal cord was considered to be the factor causing a fatal outcome. In our case no spinal abnormalities were found. The attacks of respiratory failure were probably caused by the maldevelopment of the larynx and trachea. In the medical history of patients with Larsen's syndrome the respiratory problems must be given special attention.

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NE MINERAL CONTENT IN WOMEN WITH COLLES' FRACTURE - EFFECT OF CALCIUM SUPPLEMENTATION

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The effect of dietary calcium supplementation on bone mineral content was studied in 40 postmenopausal women with Colles' fracture. The participants were divided into two groups which were given either placebo or 1 g of calcium per day. The bone mineral content of the femur was determined before and after 1 year of medication.

Women with Colles' fracture were found to have the same mineral content in the femur as age-matched controls without fractures. Calcium supplementation had no significant effect on the bone mineral content.

Key words: osteoporosis, fractura radii, dietary calcium, bone mineral absorptiometry.

Accepted 1.xi 77

Many women have a high incidence of Colles' fracture (Alffram & Bauer 1962). This is at least partly explained by a reduced mechanical strength of the skeleton due to the related loss of bone tissue and mineral content in women normally begins in the third decade (Garn et al 1969). The etiology of the loss of bone is not known although several factors, such as dietary calcium deficiency, have been proposed (Nordin 1960). The aim of the present investigation was to (i) collect data on the bone mineral content of women with Colles' fracture and, (ii) to study the effect of dietary calcium on the bone mineral content of these women.

MATERIAL AND METHODS

Forty postmenopausal women with previous Colles' fracture of the distal forearm volunteered for the study. All had sustained fractures approximately 3

years previously. Twelve patients had had repeated unilateral or bilateral Colles' fractures.

The mineral content of the patients with previous fractures, measured as described below, was compared with that of age-matched controls without fractures. The controls comprised 15 female staff members and 12 women drawn at random from the Stockholm population. The latter had participated in a study of the bone mineral content in a normal population (Dahlén & Lanke 1974). The age was 60 ± 3 (mean \pm s.d.) years in the fracture as well as the control groups.

In order to study the effect of calcium supplementation, the patients with Colles' fracture were divided randomly into two groups which were given either placebo or calcium tablets (Calcium Sandoz® 0.5 g, one tablet twice daily). Mineral measurements were made before and after 1 year of treatment. Four patients who discontinued the medication (1 calcium and 3 placebo) were excluded from the study. The actual daily supplement on an average was 0.8 g calcium, estimated on the basis of information received from the patients and from our records.

The bone mineral content was determined by X-ray spectrophotometry (Jacobson 1964, Gustafsson et al 1974). In this method the

skeletal part under examination is positioned by fluoroscopy and automatically scanned with a beam of two energy levels from an X-ray tube. The attenuation of the beam is recorded as a profile giving the mineral content expressed in mg/mm. The femoral neck and shaft were chosen for measurement of the mineral content (cf. Dalén & Jacobson 1974). Earlier investigators have used the non-injured forearm as the measuring site. This was not done in the present study, since several patients had had bilateral Colles' fractures. The statistical evaluations were made according to Student's *t*-test.

RESULTS

As seen in Table 1, there was no significant difference in the mineral content of women with and without Colles' fracture ($P > 0.05$).

Table 2 shows the percentage change in mineral content in the fracture group during 1 year. The patients given placebo lost on an average 1 per cent which is in accordance with the normal mineral loss in this age group (Dalén & Jacobson 1974). The patients given calcium supplement increased their mineral content by 3 per cent on an average. Thus difference between the placebo and

calcium groups was, however, not significant ($P > 0.05$).

DISCUSSION

In the present study women with Colles' fracture were found to have the same mineral content in the femur as the controls. The related loss of mineral in the femur is of the same magnitude as in other parts of the skeleton (Dalén & Jacobson 1974) and mineral content of the forearm correlates with that of the whole skeleton (Chestnut III *et al.* 1973). Thus, the lack of difference in femoral bone mineral content between women with fractures and controls is probably representative of the whole skeleton.

Westlin (1974) found that women with Colles' fracture were slightly leaner and had somewhat lower mineral content in the uninjured forearm than controls. The rate of loss of bone mineral with age was, however, not increased. The author's interpretation of these findings was that women with Colles' fracture have a constitutionally low mass

Table 1 Bone mineral content in women with lower forearm fractures ($n=40$) and controls without fractures ($n=27$). The age was 60 ± 3 (mean \pm s.d.) years in both groups

	Control group		Fracture group		Difference		
	Mean \pm s.d.		Mean \pm s.d.		%	<i>t</i>	<i>P</i>
	(mg/mm)		(mg/mm)				
Femur, neck	256	42	258	46	+1	0.2	>0.05
Femur, shaft	430	69	422	58	-2	0.5	>0.05

Table 2 Percentage change in bone mineral content during a period of 1 year in women with Colles' fracture. The patients were divided randomly into two groups which were given either calcium supplement ($n=19$) or placebo ($n=17$). The age was 60 ± 3 (mean \pm s.d.) years in both groups

	Placebo		Calcium		Difference		
	Mean \pm s.d.		Mean \pm s.d.		%	<i>t</i>	<i>P</i>
Femur, neck	-1.6	7.8	+2.9	11.3	+4.5	1.4	>0.05
Femur, shaft	-0.4	5.8	+3.7	7.7	+4.2	1.8	>0.05
Femur, mean of both sites	-1.1	5.6	+3.3	7.8	+4.4	1.9	>0.05

ent in the forearm rather than accelerated mineral loss.

orseman (1976) also determined the mineral content of the distal forearm, but found no clear difference between a group with fractures and a control group. The results of these studies indicate that men with Colles' fracture differ only slightly from controls and that the majority of men with Colles' fracture have a mineral content within the normal range for their age. Men in this age group have a lower bone mineral content than premenopausal women. The high incidence of Colles' fracture in premenopausal women may therefore be explained by the age related bone loss. Within this high risk group factors other than the bone mineral content probably determine which men will develop Colles' fracture. One such factor may be the degree or frequency of trauma.

In the prospective part of the present study, patients treated with calcium increased their mineral content, although not significantly. Thus, no definite conclusions can be drawn as to the beneficial effect from calcium supplementation. Certainly, calcium is a necessary component of the diet for the maintenance of a normal skeleton, but the requirements of calcium in various age groups are not known. Elderly people show a tendency to decrease their calcium intake (Hurxthal & Vose 1969) sometimes because of lactase deficiency (Burge et al 1967), and low calcium intake is low compared to losses in the gut, kidneys and skin (Lutwak 1969).

Dietary calcium supplementation has been found to increase the bone mineral content in patients with periodontal disease (Lutwak & Hulston 1973) and in normal elderly people (Albanese et al. 1973), but not in patients with spinal osteoporosis (Shapiro et al 1975). In this connection it is of special interest that relations with high calcium intake are not directed against bone loss (Garn et al 1969). This indicates that calcium deficiency is not the only factor involved in the etiology of age related bone loss.

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RECURRING DIGITAL FIBROMAS OF INFANCY

Case Report

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A case of recurring digital fibromas of infancy, with bilateral absence of the second metatarsal and deformed third metatarsal, is reported.

Key words digital fibroma, recurring, infancy

Accepted 4.xi 77

Recurring digital fibromas of infancy is a rare condition, the clinical features and behaviour which have been discussed in detail by Lee (1965). The published reports of the occurrence of this disease are scanty (Grunnet al. 1973, Bloem et al. 1974). We report one such case, believing it to be the first reported in India.

CASE REPORT

11 month-old female infant was brought to the paediatric Clinic of JIPMER Hospital Pondicherry, with a history of progressive swellings of the distal parts of the fingers, one on the left and four on the right hand associated with flexion contractures of the second and third deformed second toes. One week after birth a small swelling was noticed on the left ring finger. Subsequently similar swellings appeared on the other fingers. The swellings increased rapidly in size. The extent and distribution of the tumours are shown in Figure 1. The most prominent growths were on the dorsolateral side of the left ring finger and on the right ring, middle and right index fingers. The tumours involved the terminal phalanges sparing the nails. There was a small growth on the lateral side of the right little finger. The tumours were firm and fleshy. The overlying skin was red and shining. The tumours were fixed to the skin and underlying tissues except for the small one on the little

finger which adhered to the skin only. There were flexion contractures of the right ring and four left fingers. Bilateral syndactyly and flexion contracture of the second toe were also present (Figure 2). The lower lip had an abundance of vermilion.

On X-rays the four radial metacarpals on the left side were seen to be short and deformed (Figure 3). There was bilateral absence of the second and hypoplasia of the third metatarsal (Figure 4).

Arteriography showed the avascular nature of the tumours (Figure 5). This was confirmed during excision of one of the tumours, no bleeding occurring during surgery. The specimen removed was a nonencapsulated greyish white fibrous mass. Histopathological examination showed that the dermis was replaced by interlacing bands of fibrous connective tissue with an abundance of collagen similar to dermatofibromas with no sign of malignancy. A section of deformed bone showed a normal histopathological appearance. The tumour tissue did not yield any viral agent in monkey kidney, vero and He-la cell lines.

DISCUSSION

According to Bloem et al. (1974) recurring digital fibromas of infancy are common in females. They arise from the fingers, and are often multiple in distribution. They start as small nodules which may increase to an



Figure 1 Fibromas on both hands



Figure 2 Flexion contracture & syndactyly of the second toe

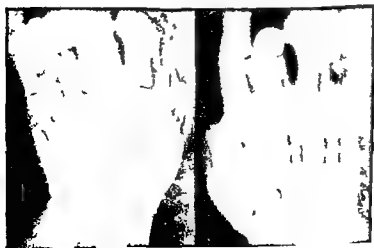


Figure 3 X rays showing & deformed metacarpals of left hand.



Figure 4 X ray showing bilateral absence of the second and hypoplasia of the third metatarsals



Figure 5 Arteriogram showing the avascular nature of the tumours

enormous size, affecting mainly the ipsilateral aspect of the distal parts of joining fingers. The covering skin may come reddish in colour and fixed to the tumour. The swellings are painless and often here to the deeper tissues sparing the nails. The cut section is avascular and eryth white in colour. Microscopically, the

dermis is replaced by interlacing bands of fibrous tissue with an abundance of collagen. The site of origin, tendency to recurrence and the presence of cytoplasmic inclusion bodies (Reye 1965, Ahlqvist et al 1967, Burry et al. 1970, Battifora & Hines 1971) are the main features by which these tumours are differentiated from other forms of fibromatosis. Bloem et al (1974) also described the presence of flexion contracture and deformed metacarpals of the affected fingers and an abundance of vermillion. The case presented here had all the characteristics described earlier, except for the presence of cytoplasmic inclusion bodies. Bloem et al (1974) also failed to demonstrate cytoplasmic inclusion bodies in their cases.

Pohjanpelto et al (1967) believed that some virus may be the aetiological factor in the development of these growths. No virus, however, could be isolated in our case in agreement with the findings of Bloem et al (1974). Some abnormal maternal hormone circulating in the blood of the new born has been presumed to play a role in the appearance of these tumours immediately after birth as the tumours quite often regress spontaneously later on (Stout 1973, Grunnet et al 1973, Bloem et al 1974). Bloem et al (1974) recommended conservative treatment. Recurrence has been reported even after excision (Jensen et al. 1957, Shapiro 1969).

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CURRENT ULNAR NERVE DISLOCATION AT THE ELBOW

Report of a Non-Traumatic Case with Ulnar Entrapment Neuropathy

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An unusual case of habitual recurrent ulnar nerve dislocation at the elbow is described. The case was complicated by non-traumatic ulnar entrapment neuropathy interfering with the patient's profession as a musician (cello).

Key words: ulnar nerve, recurrent dislocation, non-traumatic entrapment neuropathy

Accepted 17 x 77

reported incidence of habitual ulnar nerve dislocation varies between 2 and 19 per cent (Linet 1896, Momborg 1903, Dubs 1918, Linnarsson & Surtro 1939, Childress 1956). Dislocation to the extent of complete forward dislocation at the internal condyle of the humerus can be present without causing any symptoms and without the knowledge of the individual. The lower incidences include only complete dislocations (Cobb 1903). The higher incidences include complete as well as incomplete dislocation.

It is suggested that recurrent dislocation of ulnar nerve at the elbow arises as a result of trauma but can also occur nontraumatically (Linnarsson 1903). In the latter case it is called 'idiopathic', 'congenital' or 'idiopathic' dislocation.

The causes of 'habitual' dislocation are, however, not clear. It is more common than the traumatic ones and usually the affected person is only aware of the dislocation when an ulnar nerve entrapment neuropathy is present.

Ulnar nerve neuritis is thus a rare diagnosis in connection with habitual dislocation of the ulnar nerve unless it is combined with trauma. In the paper reports, however, a case of non-

traumatic ulnar nerve neuritis in a patient with habitual dislocation. The disability was so great that it was necessary to perform an ulnar nerve transposition. The diagnosis and the operative procedure is discussed.

CASE REPORT

The patient was a 21-year-old student of music and had no previous history of health problems. He

was unable to play the cello with the elbow flexed over 90° holding the chords. There was a slowly progressing sensation of numbness occurring in his ulnar fingers and pain at the elbow. The same sensations occurred in his right arm when using the bow (Figure 1). There was no history of trauma to the elbows.

Clinical examination revealed the ulnar nerve sliding in front of the ulnar epicondyle when the elbows were flexed. Registration of the conduction velocity in the ulnar nerve at the elbows (Table 1) comparing elbows flexed and elbows fully extended showed a decrease in the conduction velocity on both sides with the elbows in 90° flexion. With the elbows extended the patient did not feel any sensations in the arm or hand, nor could any

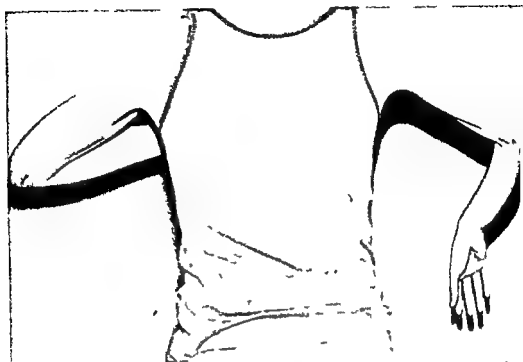


Figure 1 The position of the arms when playing the cello. Note the scars after the ulnar transpositions.

decreased sensibility in the ulnar nerve area be found. X-ray examination of the elbows showed no

There were no symptoms or signs of or possible causes of the pain such as rheumatoid arthritis (Chang et al 1972), post-traumatic arthritis, cervical syndrome, etc.

The patient was operated on with transposition of the ulnar nerve on both sides. The operation was performed in a bloodless field. The nerve was dissected free for about 5 cm proximal and distal to the ulnar epicondyle, mobilized and adapted in front of the epicondyle. The adaptation was made by a few sutures in the soft tissues around the nerve. Mobilization was started immediately after the operation.

Four weeks postoperatively the patient was to take up his cello playing again, now without discomfort. A second nerve conduction test was made 6 weeks after the operation using the same procedure as before the operation. This showed no significant difference in the conduction velocity of the ulnar nerves on either side with elbows to flexed 90° and in full extension.

DISCUSSION

Complaints of numbness in the ulnar area of both hands are very common in orchestra

Table 1 Ulnar nerve conduction

		Full extension in the elbow	90° flexion in the elbow
Preop test	Right	67 m/second	57 m/second
	Left	67 m/second	52 m/second
Postop test	Right	•63 m/second	62 m/second
	Left	•74 m/second	79 m/second

* Nerve conduction values obtained on various occasions from the same nerve can differ depending on the position of the electrode.

cute This particular person - being a scian - certainly found it disturbing to his ying of the cello Having diagnosed an ulnar ve neuritis on the basis of recurrent locations of the nerve it was necessary in form an ulnar nerve transposition Unposition of the ulnar nerve is a simple rative procedure However, perhaps it uld be of value to point out some details of operative procedure and the postoperative e The nerve should be dissected free a ficient distance proximally and distally to epicondyle so that it is possible to place the ve in its new position without stretching it armonth 1943, Childress 1956, Levy & felberg 1972) Moreover, we do not rotate any form of firmer fixation of the ve to keep it in the anterior position Such cedures involve the risk of the development strangulating fibrotic processes We think it very important also to start exercises mediately after the operation in order to vent scar fixation around the nerve Childress (1956) classified ulnar nerve remobility into two groups: type A and e B In type A the nerve moves out of its n-condylar groove on the up of the humeral condyle when the elbow is maximally ed, i.e. subluxation occurs in extreme non. Type B hypermobility means that the ve passes completely across and anterior to epicondyle when the elbow is flexed more n 90° Our case had a hypermobility of type B pe B possesses greater mobility and is said be more susceptible to friction neuritis obb 1903, Dubs 1918, Learmonth 1943, Childress 1956) This theory is supported by case

Childress (1956) found ulnar nerve dislocations in 16.2 per cent of 1,000 selected individuals (2,000 ulnar nerves), none of whom knew that he had such an anomaly Momborg (1903) discovered in the military hospital in Spandau an incidence of the anomaly of 19.8 per cent among 140 soldiers. In non-traumatic cases of habitual ulnar nerve dislocation it is known that severe symptoms rarely occur and there is seldom need for operative intervention It is the traumatic cases which give rise to all the cases which have been operated on with a few exceptions such as in our case.

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ABDUCTION CONTRACTURE OF THE SHOULDER

A Report of Two Patients

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Two cases of winged scapulae due to fibrosis of the deltoid muscle are reported. The fact that these two patients were healthy and well prior to injections suggests that intramuscular injection is the causative factor. Treatment by simple division is satisfactory.

Key words: contracture, deltoid muscle, fibrosis, intramuscular injection, winged scapulae.

Accepted 29 XII 77

Contracture and limitation of major peripheral joints due to adjacent inflammation and fibrosis has been reported with increasing frequency. Altered knee motion caused by quadriceps fibrosis has been well described and documented. However, only ten patients with fibrosis of the deltoid muscle leading to abduction contracture of the shoulder have been reported (Bhattacharyya 1966, Hill et al 1967, Goodfellow & Nade 1969, Wolbrink et al 1973, Branick et al 1976). We are presenting two additional cases and our experience with this peculiar deformity.

CASE REPORTS

Case 1 A 9-year-old girl was seen with prominence and winging of both scapulae. The

deformity was accidentally detected by an elementary school teacher who found that the patient had difficulty in bringing both of her arms to her torso. She had always been well except for a history of upper respiratory infections during childhood. Her history also revealed that she had received quite a number of intramuscular injections into her deltoid regions with each transient illness. Inspection showed prominent scapulae in the standing position with a depressed groove at the junction of the intermediate and posterior parts of the deltoid muscle (Figure 1A). A hard bony structure was palpable in the depressed groove between the acromion and the deltoid tuberosity of the humerus. The range of motion of both shoulders was free except for a bilateral abduction deformity, i.e. loss of ability to bring the arms to the sides of the trunk (Figure 1B). Winging of the scapulae was exaggerated on shoulder adduction. Significant

shoulder joint was not seen roentgenographically. Bilateral exploration of the deltoids showed a fibrous band in the intermediate part of the muscle. The band originated at the scapular spine and acromion, extending to the insertion of the humerus. Transverse division of the fibrous band and gentle graduated abduction of the arm immediately relieved the abduction deformity. Microscopic examination showed fibrosis. Postoperative mobilization of the shoulder

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Figure 1A The winging of the scapulae with motion of the deltoid is clearly shown



Figure 1B The patient is unable to bring the arms to the torso



Figure 2A The groove in the mid-portion of the arm is evident

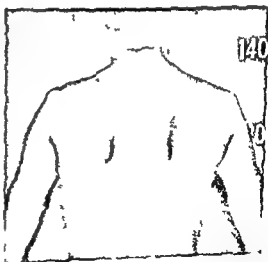


Figure 2B The patient cannot bring her arms to the chest wall and the medial borders of the scapulae are prominent

began as soon as the patient was able to tolerate it. Follow-up at 11 years showed the abduction deformity was absent in both shoulders and there was full range of motion.

Case 2 A 43-year-old housewife was seen with a 1-year history of winging of both shoulder blades which disturbed her sleep because of pain in the area of the medial angle of both scapulae. About 1

injections in both deltoid muscles for the past 2 years for a purported chronic anemia. No similar deformity was noted in the other family members. On examination a groove over the middle deltoid extending from the acromion to the deltoid tubercle of the humerus was noted (Figure 2A). There was also accompanying winging of the scapulae (Figure 2B) which was most prominent on adduction of the arm and disappeared upon elevation of the arm to approximately 60°. Adduction of the arms was blocked by a fibrotic band at 30° of fixed abduction. The range of motion of the shoulders was otherwise normal.

Exploration of the deltoid muscles revealed a tight band extending from the acromion to the humerus. Simple division of this band did not fully correct the deformity in either shoulder. By gentle adduction of the arms several tight fibrous bands were palpable in the middle portion of each deltoid muscle. Release of the contracture was

only after division of the bands. A portion

fibrous tissue was resected and microscopic

showed degeneration of the muscle

fibres and fibrosis. No immobilization

after surgery. The shoulders were, for all intents and purposes,

DISCUSSION

Abduction contracture of the winging of the scapulae is a due to fibrosis of the deltoid muscle the original report of three cases (Sato et al.), an additional seven cases been published (Bhattacharyya 1966, al. 1967, Goodfellow & Nade 1969, Wn et al 1973, Branick et al. 1976). deformity is comparable to that of quadriiceps fibrosis (Gunn 1964). Several causative factors suggested from the reports include developmental defect (Wolbrink et al 1973) congenital progressive fibrosis (Bhattacharyya

1966), and injection (Gunn 1964 Br al. 1976).

Intramuscular injections are given frequently by local practitioners in this One of the present authors (YSH) collected 24 cases of fibrosis of the muscle (Hang 1978), resulting in an abduction external rotation and extension hip defect. This allied disorder has been seen increasing frequency. The two cases here, together with recent observations patients with gluteal fibrosis, strongly suggest that repeated intramuscular injections are an important causative factor. The absence of similar affection in other family members of these two patients more or less predicts a genetic origin.

Simple division of the fibrotic band is inadequate, although excisional resection of the band has been recommended by (Bhattacharyya 1966, Hill et al. Wolbrink et al. 1973). This clinical entity is amenable only to surgery and the result is satisfactory. We believe the condition is more common than has been documented.

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LUMBAR INTERVERTEBRAL DISC HERNIATION IN THE YOUNG

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A survey of 37 young patients, 10 to 18 years of age, with lumbar intervertebral disc herniation is presented. Local physical findings and pain in straight leg raising are often more marked in the young adults, whereas pain may be slight or even absent. Neurological

...
surgical treatment good results were obtained in nearly all cases.

Key words: disc herniation lumbar spine, children adolescents

Accepted 17.x.77

... ahren in 1946 was the first to report surgical treatment for lumbar intervertebral disc herniation in a child. Since then few papers on this subject have appeared in the literature. Lumbar disc herniation in children and adolescents is uncommon, the incidence varies between 0.4 per cent (Webb et al. 1954) and 1.3 per cent (O'Connell 1960) of all cases of disc herniation.

Our impression is that recognition of this syndrome often is delayed in teenagers. The reason may be that symptoms and signs in this age group differ from those in adults, as found by Rugtveit (1966) and Day (1967). Because of its rarity physicians may pay too little attention to this syndrome in the young (Weiss & Raskind 1967, Bradford & Garcia 1971).

The purpose of the present investigation is to draw attention to this condition in young patients, in order to encourage earlier diagnosis and treatment.

MATERIAL AND METHODS

The material consists of 37 cases of lumbar intervertebral disc herniation in patients between 10 and 18 years of age, treated in Sophies Orthopaedic Hospital or in Kronprinsesse Martha's Institute from 1965 to 1976. During the same period a total of 1016 patients were treated for sciatica.

All of the 37 patients were examined by a neurologist, and in all a reflexology was performed. In 36 patients the diagnosis was verified by operation. One patient with atypical clinical findings and a positive reflexology refused operative treatment.

All patients were given a follow-up examination. The survey is based on information obtained from the records and a re-examination of radiographs.

RESULTS

The age and sex distribution is shown in Figure 1. The two youngest patients were

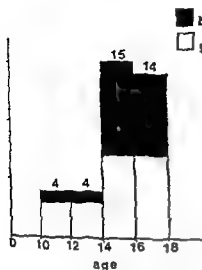


Fig. 1 Age and sex distribution in 37 patients with lumbar intervertebral disc herniation.

old. Serious low back pain sciatica or were the main symptoms in 24 patients. Nine felt only slight pain, and four had pain in all (Table 1). In eight cases the pain was localized to the leg only. Postural disturbances were the major complaint in patients, back stiffness in three and gait problems in one of the patients.

One of the patients had a history of major trauma. The duration of the symptoms before accurate diagnosis and treatment varied between 3 months and 6 years on average 20 months.

The correct diagnosis was made by the referring physician in only 14 of the patients, the scoliosis was suggested in 9 cases (Fig. 2).

Physical examination revealed abnormality of posture, spasm of the erector spinae muscles and reduced mobility of the spine in patients (Table 3). Nineteen presented with an obvious scoliosis. A distinct kyphosis was found in six patients and the rest had raised or straightened out lumbar lordosis. The straight leg raising test was positive in 34 cases being limited to 30° or less in 34 cases. A crossed positive elevation test of 80° was found in 24 patients. Three

Table 1 Dominating symptoms in 37 young patients with lumbar intervertebral disc herniation.

Pain	24
Back pain only	7
Back pain and leg pain	9
Leg pain only	8
Postural disturbances	9
Back stiffness	3
Gait problems	1

Table 2 Diagnosis on referral in 37 young patients with lumbar intervertebral disc herniation

Sciatica	14
Scoliosis	9
Back pain	5
Leg pain	3
Abnormal gait	2
Back stiffness	2
Hip disease	1
Bechterew's disease	1

patients had a markedly restricted straight-leg raising test without any feeling of pain.

Neurological examination was completely normal in 15 patients (Table 3). When a neurological deficit was found it was usually of a minor nature.

Radiographs of the lumbo-sacral spine revealed congenital abnormalities in 12 patients, asymmetry of the distal lumbar vertebra in eight and spina bifida in four cases. Radiculography was positive in all patients, at the L4-L5 level in 22 and at the L5-S1 level in 15. In a few patients a short and widened nerve root sheath was the only pathological finding.

Conservative treatment was tried initially in 29 of the patients. Eventually all but one were treated surgically. A laminectomy was performed at one level, on one or both sides. Operative findings correlated well with the radiculographs. Free disc herniation or definite disc protrusion were found on one side only in all cases. In two patients the bulging disc contained a grumous mass. Histological examination of the removed disc was not performed.

Table 3 Comparison of the physical findings in teenagers and lumbar intervertebral disc herniation

	Present series (37 young people)		Ravig (1949) (100 adults)
	No	Per cent	Per cent
List			71
List or scoliosis	37	100	
Distinct scoliosis	19	51	
Kyphosis or decreased lumbar lordosis	37	100	88
Reduced mobility of spine	37	100	100
Muscle spasm	37	100	100
Straight-leg raising positive	37	100	98
Straight-leg raising 30° or below	34	92	56
Abnormal gait	9	24	
Neurological findings			
Normal	15	41	
Muscle atrophy or hypotony	16	43	94
Paresis	11	29	38
Sensory deficit	8	21	76
Depressed or absent tendon reflexes	4	10	54
Disturbance of bladder function	0		12

There were no surgical complications, and the immediate result was most satisfactory as far as relief of pain was concerned. The spinal contractions gradually disappeared spontaneously in all but one patient, whose persisting was treated successfully by a corrective plaster cast (Figure 2).

The follow-up period ranged from 10 years to 6 months with an average of 5 years and 6 months. The result was good in 31 patients who had no subjective symptoms and normal objective findings. Five patients had minor complaints. One patient had relapse of back pain and sciatica and was reoperated a few months after primary surgery. Radiculography showed changes suspected of being disc herniation at the same level as before. At surgery nerve root adhesions were found, but no disc herniation or protrusion.

DISCUSSION

The proportion of teenagers among all patients treated for lumbar intervertebral disc herniation was 3.6 per cent which is relatively

high. However, a selection has probably taken place, because patients with scoliosis and other special back problems have been referred to our hospitals from regions outside the ordinary referral area. There was a preponderance of females, whereas males dominate in most other series of disc herniation in both young people (Bradford & Co 1971) and adults (Ravig 1949).

Trauma was frequently present in the history of our patients. Most authors have made the same observation.

Nelson et al (1972) found no significant difference in the occurrence of trauma as a precipitating factor in disc disease in young people and adults. Trauma is pre-

Figure 2 An 11-year-old boy referred for diagnosis of scoliosis. He had no pain at all. He presented with a left-sided thoracic scoliosis of 30° (a, c) and spasm of the paraspinal muscles. The straight-leg raising test was positive at 10°. Radiculography showed a herniation on the right side at the L₄-L₅ level. Three months after surgery the scoliosis was unchanged, but the spine straightened completely in a corrective plaster cast (d).



not the only cause of intervertebral disc herniation, as the disc is not the weakest part of the spine (Brown et al 1969), and disc degeneration may start early in life.

Conflicting information exists as to whether or not symptoms and signs differ in children and adult patients suffering from intervertebral disc herniation. Some authors have stressed that while symptoms are often minor, objective findings dominate in children (Rugtveit 1966, Day 1967). Others have found no significant differences between young people and adults as regards symptoms and signs (Epstein & Lavine 1964, Weiss & Raskind 1967).

Pain was the main symptom in only 24 of our patients, four had no pain at all, whereas pain is the dominating complaint in nearly all adult patients (Røvig 1949). Other discomforts such as postural disturbances and back stiffness are also felt in the great majority of adults.

Clinical examination revealed impressive pathological findings in all cases, viz scoliosis, kyphosis or reduced lumbar lordosis, limitation of spinal movement and muscle spasm. A markedly restricted straight-

raising test was also typical in cases of intervertebral disc herniation in young patients. The test was positive also in patients without irradiating pain, and limitation was not always accompanied by pain. Similar observations were made by Key (1950).

Røvig (1949) made a clinical study of 100 adult patients with lumbar intervertebral disc herniation. He also found distinct physical signs (Table 3). However, obvious scoliosis and markedly restricted straight-leg raising test were more frequent in younger patients, while positive neurological findings were more frequent in adults. In our series the neurological deficits were of little significance.

Though there are no essential differences in symptoms and signs in young as opposed to adult patients with disc herniation, it seems that local physical findings and limitation in straight-leg raising tend to be more marked while pain may be slight or even absent in

young people. Also there is an obvious contrast between the clinical impression of nerve root compression and the minor neurological deficits in teenagers. The differences in the symptoms and signs in the two age groups may be explained by the mobile spine of the young prevent pressure.

The intervertebral disc herniation syndrome in children and adolescents is characteristic, and it should not be difficult to recognize provided awareness of the syndrome is aroused.

It is our experience that conservative treatment often fails in teenagers. The use of surgery, however, were gratifying. This is in accordance with most authors (Epstein et al 1972, Bulos 1973) though Taylor (1966) found that the results of surgery were not satisfactory.

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not the only cause of intervertebral disc herniation, the disc is not the weakest part of the spine (Brown et al 1969), and disc degeneration may start early in life.

Conflicting information exists as to whether or not symptoms and signs differ in children and adult patients suffering from intervertebral disc herniation. Some authors have stressed that while symptoms are often minor, objective findings dominate in children (Rugtveit 1966, Day 1967). Others have found no significant differences between young people and adults as regards symptoms and signs (Epstein & Lavine 1964, Weiss & Raskind 1967).

Pain was the main symptom in only 24 of our patients, four had no pain at all, whereas pain is the dominating complaint in nearly all adult patients (Røvig 1949). Other discomforts such as postural disturbances and back stiffness are also felt in the great majority of adults.

Clinical examination revealed impressive pathological findings in all cases, viz scoliosis, kyphosis or reduced lumbar lordosis, limitation of spinal movement and muscle spasm. A markedly restricted straight-leg raising test was also typical in cases of intervertebral disc herniation in young patients. The test was positive also in patients without irradiating pain, and limitation was not always accompanied by pain. Similar observations were made by Key (1950).

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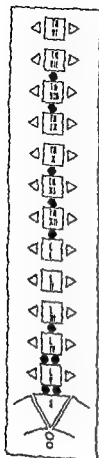
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The intervertebral disc syndrome in children and adolescents is characteristic, and it should not be recognized provided awareness of the syndrome is aroused.

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the sites of pyogenic spondylitis

The course of the disease Three patients became acutely ill with septic fever and back pain. In these cases blood culture was positive. In the remaining cases the onset of the disease was insidious.

Symptoms The general symptoms were fever, weight loss and fatigue. An acute onset of the disease was associated with septic fever (40°C). In the insidious cases the patients were subfebrile. All patients had back pain, which usually was localized. This was the symptom for which the patients consulted a physician.

The primary focus The possible primary focus of bacteraemia was revealed by the history in three cases. One patient had had tonsillitis 6 weeks before the onset of symptoms. Another patient had caught erysipelas of the hands 2 weeks before the onset of symptoms, and a third patient had had a tooth fixed 10 days before the symptoms began.

Predisposing factors Factors predisposing to infection were present in four cases. One patient showed agranulocytosis due to thyrostatic therapy. Two patients had latent diabetes, and one was a chronic alcoholic.

Physical findings Percussion revealed local tenderness at the site of infection in all patients. Neurological signs were found in two patients. One had transient signs originating in the cauda equina, the other showed a hyper-reactive Achilles reflex.

Laboratory findings The ESR was clearly elevated in all patients, the values ranged from 66 to 141. Slight anaemia ($<120\text{ g/l}$) was observed in seven

Table 1. Short case histories

no.	Age	Local symptoms	General symptoms	Predisposing factors	Interval between presenting symptoms and diagnosis (months)
32		Back pain	Fever	Agranulocytosis	2
54		Back pain	Fever	—	3
36		Back pain	Fever	Chronic alcoholism	3
			Weight loss		
			Fatigue		
62		Back pain	Weight loss	Latent diabetes	3
17		Back pain	Fever	—	1
54		Back pain	Weight loss	—	4
38		Back pain	Fever	—	
			Weight loss		1
33		Back pain	Fever	—	1.5
62		Back pain	Fever	Latent diabetes	3
78		Back pain	Fever	—	

and mild leucocytosis ($>10\,000$) in four cases. The patient showing agranulocytosis had a haemoglobin value of 76 when it was at its lowest but this was attributed to his haematological disease rather than to the infection. Alkaline phosphatase was elevated in six patients.

Bacteriology Blood culture was positive in three patients. *Staphylococcus aureus* was identified in two cases. *Streptococcus faecalis* in one. A sample of pus from the site of infection was obtained at exploration in one case. *Staphylococcus aureus* was demonstrated on culture of this sample. The ASTA values were elevated (≥ 4) in eight cases (range 4 to 32).

Radiological findings Narrowing of an intervertebral space was observed in all patients (Figure 2). A wedge-shaped deformity was noticed in three patients and an abscess shadow in two



Figure 2b



Figure 2 36-year old male (R.R.) who became acutely ill with septic fever and back pain. (a) Two weeks after the onset of symptoms slight narrowing of an intervertebral space. (b) Five weeks after onset of symptoms vertebral collapse. Eleven months' results.

of the vertebral bodies varying in degree observed in eight patients during an observation period of 6 to 30 months.

Isotope scanning Scanning with Tc^{99m} was carried out in nine patients, seven of whom in an early stage of the disease. A significant uptake was noticed in five of these cases.

Average interval between the onset of symptoms and the diagnosis was 3 months, range 1 to 10 months. All patients were hospitalized for 3 to 6 months before a definite diagnosis could be made.

Treatment All patients were admitted to the Surgical Department. In the early stages of the disease the treatment consisted of bed rest and antibiotics. The average duration of hospitalization was 64 days, range 36 to 99 days. Antibiotics were given for 142 days on the average, range 45 to 321 days. If blood culture was positive the choice of antibiotic depended on the sensitivity of resistance. Otherwise an antibiotic generally known to be effective against *Staphylococcus aureus* was given, e.g. Cloxacillin[®], Erythromycin[®] or Erythromycin[®]. The patients were followed favourably to the treatment. All recovered and became symptom free.

DISCUSSION

Initially, febrile patients with a high ESR have been treated with antibiotics for a long time without any knowledge of the cause of infection of the spine and may thus become symptom free under a wrong diagnosis. It is also possible as Martin (1970) has pointed out, that many patients who in the past have been treated for tuberculous spondylitis and who rapidly died, in fact suffer from spondylitis caused by pyogenic bacteria. A specific bacteriological diagnosis must be made. When the disease has an acute onset, blood culture is usually positive. If the onset is insidious, blood culture is usually negative. A blood culture performed with a trocar under TV control is technically difficult, but this method has increased in popularity (Snoeppen 1976). The possible complications are abscess and meningitis. Ambrose et al. (1972) and Lewis et al. (1972) successfully cultured bacterial samples by needle

aspiration. Holzman & Bishko (1971) disputed the necessity of specific bacteriological diagnosis and resistance determination and thus also of early exploration. This standpoint is justified with regard to the spondylitis addicts. These cases are often caused by gram-negative bacteria resistant to antibiotics. In Finland, exploration is not absolutely necessary, since *Staphylococcus aureus* is the most frequent causative agent and the diagnosis can often be supported by serological and bacteriological tests. Von Schwagerl (1969) proved the diagnostic validity of ASTA-determination in deep, progressing infections caused by *Staphylococcus aureus*, especially in spondylitis. A diagnosis based on the clinical course of the disease, the radiological findings and serobacteriological tests will often suffice for the institution of therapy. In fact a positive reaction to the therapy is diagnostic. If a malignant or other tumour cannot otherwise be excluded, exploration is of course mandatory.

Radiological demonstrable lesions in pyogenic spondylitis may develop very quickly. A slower process is an important diagnostic criterion in tuberculous spondylitis. Isotope scanning is of less value diagnostically because the method is non-specific. Still this technique may be used in both the diagnosis and the follow-up of pyogenic spondylitis. It is a good indicator with regard to the reactivation of an infectious process (Kemp et al 1973) and roentgenographically dubious primary lesions and recurrences (Fellander & Lindberg 1966).

The treatment of pyogenic spondylitis is usually conservative, antibiotics and bed rest may be recommended. A plaster bed, as was formerly used, is not required. Operation is indicated if conservative treatment fails and there is progression of neurological signs.

An early diagnosis of the disease is difficult. Fever, back pain, a high ESR, slight anaemia and mild leucocytosis are typical features, but a similar clinical picture is seen in many other diseases, e.g., malignant tumours. Because of the general symptoms, the back pain may easily be ignored and the patient may therefore be subjected to unnecessary examinations and

procedures Waldvogel et al (1970) stated that an early diagnosis depends on a clinical suspicion. If the diagnosis is made early enough, neurological complications are rare and the prognosis is good.

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BONE SCINTIGRAPHY IN EARLY DIAGNOSIS OF PERTHES' DISEASE

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^{99m}Tc-pyrophosphate bone scintigraphy was performed in patients with Perthes' disease in the radiological initial stage and within 4 months after the onset of symptoms, and in patients with transient synovitis of the hip joint. In Perthes' disease there was decreased activity in the capital femoral epiphysis. In cases with synovitis a diffusely increased activity was found. A correct diagnosis of Perthes' disease was possible at a time when the radiological findings were minimal or even prior to any radiological findings. Increased activity might have been expected if the aetiology of the disease was an aseptic coxitis, or if the increased radiological density was due to new bone formation. Also in abortive forms of Perthes' disease a decreased activity was found. This indicates that a period of decreased blood flow to the epiphysis is not bound to be followed by the typical radiological course of the disease.

Key words: bone, epiphysis, hip, Legg Perthes' disease, osteochondritis, necrosis, radioisotopes

Accepted 15.x.77

The pathology of Perthes' disease can be described as a vascular disturbance leading to necrosis and subsequent revascularization of the capital femoral epiphysis (Jonsäter 1953, McKibbin & Ralls 1974, Jensen & Lauritzen 1976). Death of bone does not produce immediate changes in its radiographic density and in the early stages standard radiographs are normal. Therefore diagnosis and treatment are often delayed. To establish an early diagnosis of bone necrosis, bone isotope techniques have been tried for many years (Lücker 1950), but were not generally accepted for clinical use until the introduction of ^{99m}Tc labelled bone seeking components.

The degree of tracer uptake is primarily a function of the blood supply to the bone (Garnett et al 1975), and may thus be used for the detection of areas with both decreased and increased vascular supply. This method has been used successfully in studying necrosis of the femoral head following fractures (Korvald & Sundsfjord 1974). The radiation dose is low and the method can therefore be used in investigating paediatric bone diseases as well. The purpose of the present paper was to investigate the possibility of using bone scintigraphy to make an early diagnosis in Perthes' disease.

MATERIAL AND METHODS

From 1974 to 1977 bone scintigraphy was performed in patients with suspected Perthes' disease. They were examined clinically, radiologically and with bone scintigraphy as early as possible. Only patients examined within the first 4 months after the onset of symptoms, having either radiographical signs of Perthes' disease in the initial stage or no positive radiographical findings at all, a total of 26 patients, were included in the present material. However, two patients were excluded because scintigraphic images were not taken with the hips in the standard position, leaving a total of 24 patients for further study.

^{99m}Tc -pyrophosphate was prepared by adding 5 ml saline eluate from a ^{99m}Tc generator to the contents of a bottle of Isolut Nyco containing polyphosphate $2.4\ \mu\text{mol}$, Na -pyrophosphate $22.4\ \mu\text{mol}$, Sn^{4+} (as chloride) $2.2\ \mu\text{mol}$. Each patient

was encouraged to drink a lot to reduce the concentration in the urogenital tract, and to urinate frequently to minimize the radiation in the bladder. No adverse reactions to the injected pharmacum were observed. The scintigraphic examination was performed with a gamma-camera (Pho/Gamma III, Nuclear Chicago) connected to a computer unit (Nuclear

Data, fifty fifty MED). Bone scintigraphic scans were taken of the pelvis and both hips with a parallel hole collimator, and of both hips in scrotal position using a pinhole collimator. When using the parallel hole collimator it was possible to compare the uptake of the tracer in the two hip regions. A detailed study of the radioactivity in the epiphysis was possible using the enlarged image produced with the pinhole collimator. In normal bone scintigrams the acetabular roof and the femoral plates reveal a high activity, whereas the epiphysis and the femoral neck show a relatively lower uptake (Figure 1).

RESULTS

Perthes' disease developed in 20 hips of 11 out of the 24 patients. Three were females and 15 males. The age varied from 2½ to 11 years, mean age 5.4 years. The right hip was involved in 13 cases and the left hip in 11 cases. The patients presented with a limp and/or pain in the involved hip. The mean duration of symptoms was 2.6 months. The



Figure 1 A 7-year-old boy with pain in the left hip region for about 2 months and restricted movement of the hip joint. (a) Radiograph reveals no pathological findings. (b) The bone scintigraphic image taken with a pinhole collimator showed slightly increased activity in the hip region, but no areas with decreased uptake of tracer. The acetabulum, femoral head, epiphyseal plate and greater trochanter are easily identified.

age of movement of the affected hip joint is reduced. Radiographs showed Perthes' disease in the initial stage in 18 hips, 13 of which showed sclerosis. Normal radiographs the first examination were found in two cases.

Scintigraphy revealed a pathological uptake with decreased activity in the capital femoral epiphysis in all cases with Perthes' disease. Increased radioactivity throughout the entire epiphysis was observed in half of the hips (Figure 2). The others had decreased activity in parts of the epiphysis. Increased activity in the hip region was not observed in any case with Perthes' disease in the early stage investigated.

Three patients had radiographically unilateral Perthes' disease at the first examination, whereas scintigraphy revealed distinctly increased activity in both hips. In one case (Figure 3) symptoms had been present for 1 month in the radiographically normal hip

Later on, radiographs showed both hips passing through the usual stages of fragmentation and remodelling. In a second patient, with symptoms from one hip only, radiographs showed bilateral involvement 4 months later. In the third patient, no radiographical changes nor any symptoms developed in the hip with decreased scintigraphical activity only.

No radiological signs of Perthes' disease were found in six patients at the time of scintigraphy. Radiographs at follow-up 4 months later were normal as well. All suffered from limping and/or pain. Decreased mobility of the hip joint was demonstrated in all these cases and in two patients the decreased mobility remained at the time of scintigraphy. Scintigraphy revealed no signs of decreased uptake of the tracer. On the contrary a slightly increased activity affecting both the proximal femoral epiphysis, the metaphysis and the acetabulum was found (Figure 1).



2 A 4-year-old boy who had been limping with his left leg for about 2 months. (a) Radiograph of left hip shows Perthes' disease in late initial stage with sclerosis and slight flattening of the epiphysis. (b) The bone scintigraphic image with a pinhole collimator shows decreased activity in the distal epiphysis.

3a

Figure 3 A 3-year-old boy

left hip (a) Ra

right hip is normal

left capital epiphysis, but also in the right radiologically normal hip

ma f
il f
only

DISCUSSION

In Perthes' disease symptoms and clinical findings are not conclusive, and diagnosis is based on radiographs only. However, the earliest radiographical changes are usually

first seen several weeks after onset of symptoms (Edgren 1965). In the present investigation it has been possible to demonstrate a pathological scintigram in cases of Perthes' disease examined during the first 4 months after onset of symptoms.

and a decreased uptake of ^{99m}Tc -phosphate in all or part of the capital epiphysis. These findings which are the results of Danigelis et al (1975), are present before any changes could be seen on radiographs.

The exact location of ^{99m}Tc -pyrophosphate uptake is unknown, but it seems to be linked to the hydroxyapatite crystals (Garnett et al 1975, Gied 1976). The degree of uptake probably depends on many factors such as capillary permeability and receptors available. But the degree of regional bone blood flow is a major determinant for the degree of tracer uptake (Siegel et al 1976). A decreased uptake in Perthes' disease may therefore be a sign of decreased blood flow to the epiphysis. If the onset of symptoms is related to a vascular disturbance leading to necrosis of the epiphysis it is reasonable to assume that ^{99m}Tc -pyrophosphate uptake increases immediately after the impairment of the blood supply. A positive scintigraphic examination should therefore be expected at the very beginning of the symptoms, and scintigraphy may thus be of great importance in the early diagnosis of Perthes' disease.

The cause of the radiological sclerosis in the initial stage of Perthes' disease has been a matter of dispute (Jonsäter 1953, Larsen & Lian 1973). In an investigation using F^{18} scintigraphy, Bohr (1973) found increased uptake even in the initial stage and supported the opinion that the increased density was due to appositional bone formation. In the present material the examination did not show any sign of increased activity in any parts of the capital femoral epiphysis even in cases with radiological sclerosis. As F^{18} and ^{99m}Tc -pyrophosphate accumulate in the same way (Garnett et al 1975), these two reports seem to contradict each other. However, the examination with F^{18} was performed relatively late and the image possibly represents a phase passing on to the fragmentation stage with revascularisation and new bone formation. In the present material the examinations were performed very early in

the initial stage within 4 months of the onset of symptoms and prior to any revascularisation and new bone formation. The results in this investigation therefore are in agreement with the histological findings of Jonsäter (1953) and indicate an initial phase of decreased blood supply to the epiphysis.

The aetiology of the decreased blood flow is obscure. Vascular occlusions, alterations in blood coagulability and a relatively insufficient blood supply in a growing epiphysis have been discussed (Hipp 1962, Chung & Ralston 1969, Rodgegerdts 1969, Bjerkreim & Trygstad 1976, Jensen & Lauritzen 1976). Furthermore, transient synovitis of the hip joint has been proposed as a cause (Spock 1959, Emr 1966, Barz & Torklus 1976). In the present investigation none of the cases with clinical synovitis had any decrease in the uptake of tracer, on the contrary, some had a diffusely increased uptake often found in cases of inflammatory disease (Hoffer & Genant 1976). The patients with Perthes' disease had no signs of increased uptake of the tracer. This would be expected if an inflammatory reaction was the primary cause of the disease.

The radiological findings in Perthes' disease change in a rather typical manner with progress and eventual healing of the disorder. However, cases with minor radiological changes and a relatively rapid improvement have been described. Sundt (1949) called these cases "abortive" Legg-Calvé-Perthes' disease, a term also used by Katz (1965). Meyer (1964) named these involvements "dysplasia epiphysialis capitis femoris", and believed they represented a separate syndrome. However, it is still uncertain whether this is merely a variant of Perthes' disease or a growth disturbance. In the present study one hip had radiographical changes corresponding to an abortive form of Perthes' disease, and the scintigraphic image showed decreased uptake of the ^{99m}Tc -pyrophosphate. In another case with decreased uptake in an asymptomatic hip and in whom treatment was started very early owing to involvement of the other hip no

radiographic changes occurred. This indicates that abortive forms of Perthes' disease may be caused by vascular disturbances. Furthermore, it indicates that a period of decreased blood flow to the epiphysis is not bound to be followed by the typical Perthes' disease which probably is due to a late revascularization and reinfarction (Sanchis et al 1973, McKibbin & Ráhlé 1974, Jensen & Lauritzen 1976, Inoue et al 1976).

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HEMIPELVECTOMY

Operative Rehabilitation Assessed on the Basis of 41 Cases

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Rehabilitation was evaluated on the basis of 41 consecutive hemipelvectomies for malignant tumours. Owing to early metastasization and death, 11 patients were not supplied with prostheses, while prosthetic fitting was attempted in the remaining 30. Of this number, 27 completed prosthetic training, with the result that 15 used their prosthesis, while 12 discarded it after some time, six because of poor general health owing to recurrence of the tumours and six because they felt that the prosthesis was too heavy and difficult to wear. Twenty three returned to work. After elimination of the most severely tumour-affected patients, there were 19 one-year survivors without recurrence. Thirteen of them were using their prosthesis every day, and thirteen had gone back to work. Serious mental sequelae were found in five patients, including four with long-lasting exogenous depressions and one with anxiety neurosis.

Key words: hemipelvectomy, malignant tumours, prosthesis fitting, rehabilitation.

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Hemipelvectomy has been well described in respect to indications, surgical technique, and survival (Gordon-Taylor et al. 1952, & Miller 1964, Ravitch & Wilson 1964, Gunboothom et al. 1966, Miller 1974). On the other hand, the literature published so far has little to elucidate the course of operative rehabilitation, and the results can have not been consistent. Rather poor results were obtained by Lewis & Bickel (1957) who could report only two users of the prosthesis among 25 survivors, by Gunboothom et al. (1966) with 24 users among 60 survivors, and by Douglas et al. (1975) who concluded, on the basis of 50 hemipelvectomies, that the prosthesis was cosmetic rather than functional and that it

was accepted by only a few patients. Better results were found by Miller (1959) who had 22 users out of 32 hemipelvectomized patients and the same number working, and by Watkins (1962) who had 8 users and 10 survivors and 6 back in employment.

On this basis we felt it would be of interest to investigate the rehabilitation of hemipelvectomized patients, including especially their use of the prosthesis and their occupational rehabilitation.

PATIENTS

In the Department of Orthopaedic Surgery U, Rigshospitalet, and Department I Orthopaedic Hospital, Copenhagen, 41 patients were subjected

Table 1 Histological classification

Type of tumour	No of cases
Osteogenic sarcoma	12
Chondrosarcoma	8
Osteoclastoma	3
Fibrosarcoma	5
Neurofibrosarcoma	3
Rhabdomyosarcoma	2
Synovial sarcoma	2
Myxosarcoma	3
Anaplastic sarcoma	1
Metastasis from cervical adenocarcinoma	1
Total	41

to hemipelvectomy during the period 1952 to 1976. Twenty-five of these operations were carried out during the period 1967–1976, a decade during which this treatment was centralized in these hospitals and they served an area with a population of about 2.5 million. This corresponds to a frequency of hemipelvectomy of 1 in 1 million of the population per annum. The sex ratio was 19 males and 22 females, age range 7 weeks to 79 years, mean 42 years. The indication was pelvic or juxtapelvic malignant tumours, including tumours of the upper part of the thigh. Table 1 lists the histological classification of the tumours.

The surgical technique was that recommended by Kung & Steelquist (1943), but often had to be modified in accordance with the regional extent of tumour. In 29 patients it was possible to preserve the gluteal muscles. At the time of surgery 35 operations were considered radical, while in 6 macroscopic tumour tissue had to be left behind. No patient died during the operation or during the first postoperative month.

As for primary postoperative complications there were 13 cases of wound infection, 11 of cutaneous necrosis, 3 of transient sphincter disturbances, and 21 patients had phantom pain requiring analgesic medication. In 18, however, the pain disappeared completely or partially, within 3 months but 3 patients went on having pain of a more permanent nature.

After the operation all patients were followed regularly until death or until the present status (March 1977). For the survivors the follow-up period from the time of the operation averaged 6½ years, ranging from 6 months to 19 years. For the deceased patients 20 months, ranging from 2 months to 7 years. Local recurrence occurred in 9 patients 2 months to 3 years (mean 13 months) after the operation, and pulmonary metastases developed in 11

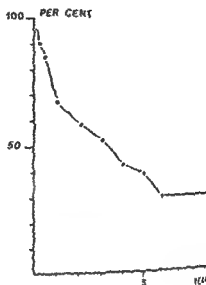


Figure 1 Survival among the 41 hemipelvized patients during the first decade after the operation. Survival computed according to the standard life table method.

patients from 0 months to 3 years 6 months (9 months) after the operation. At the time of present analysis 16 were alive and 25 had died from the tumour and 3 from other causes. Figure 1 illustrates the survival.

REHABILITATION

In principle, an attempt was made in all the patients with a prosthesis. However, the course after operation was to a great extent influenced by the underlying disease. In 10 patients, major patients developing metastases and succumbing within the first year. 1) Therefore, no prosthesis was made in these patients. The first 6 of the remaining patients were primarily supplied with a hemipelvectomy prosthesis with a bucket-type socket and hip lock, when remaining 24 were primarily supplied with the Canadian hip exarticulation prosthesis modified for hemipelvectomy (Harris & McQuirk 1969). Three of the 30 patients whom a prosthesis had been made were unable to carry through the programme, two of them because of metastasization and one because of

ession. Of the remaining 27 fitted with a thesis, 12 later discarded it, because of general health due to recurrence and use of fitting problems or because they felt prosthesis was too heavy and difficult to

Thus, only 15 patients wore their prostheses regularly up until the time of analysis until they died

occupational rehabilitation too was ended by the underlying malignant disease. Nine died before rehabilitation, 23 returned to work, and 9 were awarded disment pension.

Eight patients had mental problems in the form of anxiety neurosis or depression. In five

of them the mental trouble was long lasting. Thus, four women aged 50-53 had episodes of depression requiring treatment and lasting for 1 year or longer. One of them committed suicide 6 years 11 months after the operation. A 35 year-old man had long lasting anxiety neurosis which led to morphine addiction.

By considering only patients who survived without recurrence for 1 year or longer, thus leaving out the most malignant cases, a better basis for assessing the consequences of hemiplectomy as such is obtained. For this assessment we have 19 patients whose use of the prosthesis and occupational rehabilitation are shown in Table 2. It will be seen that 13

Table 2 Prosthetic and rehabilitation status of patients surviving without recurrence for 1 year or longer after hemiplectomy

No.	Sex	Age at op	Occupation		Using prosthesis
			before	after	
1	F	23	clerk	clerk	daily
2	F	49	shop assistant	(part time) shop assistant	daily
3	M	42	teacher	(part time) teacher	never
4	M	12	schoolboy	(full time) bicycle mechanic	daily
5	M	26	electrician	(full time) radio mechanic	daily
6	M	35	shopkeeper	(full time) shop assistant	daily
7	M	19	bricklayer's apprentice	(full time) engineer	daily
8	F	68	old age pensioner	(full time) old age pensioner	daily
9	F	51	shop assistant	clerk (part time)	daily
10	M	7 wks.	—	—	daily
11	F	50	housewife	disablement pensioner	never
12	F	52	housewife	disablement pensioner	never
13	F	53	housekeeper	disablement pensioner	never
14	M	57	civil servant	disablement pensioner	never
15	M	30	ship builder	optical draughtsman (full time)	never
16	F	55	music teacher	music teacher (full time)	daily
17	M	37	counterman	clerk (full time)	daily
18	M	30	clerk	clerk (full time)	daily
19	F	49	housewife	housewife (full time)	daily

were using their prosthesis daily and 6 not at all. It is apparent also that out of 17 who had been working prior to the operation only 9 had been able to go back to full-time work, while 4 were working part-time and 4 had been awarded disablement pension. One of these 19 patients (Case 1 in Table 2) had been through a normal pregnancy and had a normal delivery 18 months after the operation.

DISCUSSION

Like Murdoch (1969), we found a frequency of hemipelvectomy of 1 in 1 million of the population *per annum*. The operation is indicated almost exclusively for malignant tumours, most often sarcomas. Therefore the postoperative course is in general characterized far more by the underlying malignant disease than by the surgical procedure as such. This makes it difficult to assess the consequences of hemipelvectomy for the patients' rehabilitation and explains the large number of patients not supplied with prostheses and not rehabilitated, also in recent publications (Higinbotham et al 1966, 1971, Witting & Wurbatz 1971, Jones 1974). It also explains the tendency of many surgeons to consider the problems relating to the rehabilitation of hemipelvectomy patients as being fairly subordinate and in all essentials solved.

However, our findings — that among tumour-free 1-year survivors about one-third of those supplied with a prosthesis later give up using it (Table 2) — reflects the appreciable difficulties involved in the wearing of a hemipelvectomy prosthesis as a rule because the patients feel it is too heavy and unwieldy and occasionally because of fitting problems. The latter applies particularly to patients whose body weight fluctuates.

Our material also illustrates the problems in occupational rehabilitation. Half the tumour-free survivors had been unable to go back to full-time work (Table 2). Mental

sequelae were somewhat more common, more severe in women. Like Enneking (1966) we believe that the cosmetic result of a mutilating procedure is of more concern to women than to men.

Thus rehabilitation of hemipelvectomy patients is still a process in which there are many losers, and thereby a process which constitutes a challenge not only to patients and their relatives, but also to the therapeutic team in charge of pre-fitting, training and occupational rehabilitation.

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IMPACTED FRACTURES OF THE FEMORAL NECK TREATED BY EARLY MOBILIZATION AND WEIGHT-BEARING

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Among 280 patients with femoral neck fractures 46 were stable having impacted fractures according to the criteria mentioned below. Treatment of patients with impacted femoral neck fractures was determined to be mobilization with partial weight bearing from the first day of admission. Among the 42 patients successful in immediate mobilization were eight whose fractures disimpacted. Three cases of avascular necrosis were recorded but no cases of non union. In order to determine the predictive signs of secondary dislocation the X ray findings were subjected to statistical analysis. The inclination of the fracture line, dislocation in valgus or varus position and the presence of retroversion did not affect the tendency to disimpaction. More than 80 per cent of the fractures healed without disimpaction.

Key words femoral neck fracture impacted stable abduction

Accepted 18 xi 77

PATIENTS

During the period March 1971 to April 1975, a total of 280 patients were admitted to the Gentofte County Hospital, Department of Orthopaedic Surgery T 2, for treatment of fractures of the femoral neck. All patients with subcapital and midcervical fractures with good contact between the fracture ends were accepted for non-operative treatment if they fulfilled the single clinical criterion of being able to raise the straight leg in the supine position. According to these criteria 46 patients had impacted fractures. This study was performed to examine the effect of immediate mobilization and weight bearing in conjunction with non-operative treatment. Four patients who could not be mobilized within 2 weeks of admission due to debility were therefore excluded. Thus the study comprises 42 patients. Age and sex distribution are shown in Figure 1.

TREATMENT

The patients were treated with immediate mobilization with partial weight bearing on two

crutches. In debile patients full weight bearing was allowed. During the first 6 weeks bi-radiographic examinations were performed to check for possible secondary dislocation. Secondary dislocation leading to instability or pain occurred in 3 patients who were operated according to the usual principles in the department.

METHODS

Antero-posterior X rays were used to determine the inclination of the fracture line of the femoral neck and the rotation of the femoral head. A valgus or varus position was observed if the fracture line was directed laterally or medially. This technique is illustrated in Figure 2 and the results are shown in Table 1. Lateral X-rays were used to register the presence of anteversion or retroversion of the femoral head. The fractures were divided into three groups: anteverted, normal and retroverted. The results are shown in Table 1. Attempts were made to determine if the fractures were radiographically impacted.

The age and sex of the patients and type of operation performed are presented in Table 1

Technique of anaesthesia

About 1 hour prior to the induction of the anaesthesia each patient received atropine 0.25 mg diazepam 5 to 10 mg i.m. Anaesthesia was induced by intravenous administration of triazepam (0.008 to 0.03 mg/kg) + fentanyl 25 to 0.05 mg/kg + pancuronium (0.1 mg/kg). Patients were intubated and normoventilated at 34–42 Torr, pO_2 110–180 Torr. Anaesthesia was maintained with O_2/N_2O (2/3 v/v) and small doses of fentanyl and pancuronium were given intravenously when necessary. Compensation for blood loss by whole blood was accurate throughout the operation.

Measurements

Venous blood was collected with a venous catheter inserted into the vena cava superior via the vena jugularis interna. The samples were immediately refrigerated in ice, centrifuged at 4°C and frozen at -40°C, until assayed. Haemolytic complement (CH50) was titrated with a Technicon Auto-analyser as described by Vargues & Tagnon (1967). Results are expressed in Units/ml (normal range 300–600 U/ml). The serum concentration in C3 and C4 was measured by an immunoprecipitation technique using a

An arterial catheter was placed in the radial artery in order to measure the arterial PO_2 , pH

Table 1 Distribution of age, sex and type of operation

Type of operation	Total	Sex		Age ^a
		M	F	
total hip arthroplasty	11	2	9	19.4 ± 6.9
non-cemented hemi arthroplasty	7	1	6	76.2 ± 1.4
cemented hemi arthroplasty	7	—	7	76.1 ± 4.8
total	25	3	22	71.7 ± 4.5

mean age in years ± SD

Table 2 Sampling times during total hip arthroplasty (THA), non-cemented / cemented hemi arthroplasty (CHP) and cemented hemi arthroplasty (CHP)

Sampling time	Arterial PO_2		Venous PO_2	
	THA	CHP (CHP)	CHP	CHP (CHP)
Start of anaesthesia	+	+	+	+
Hip dislocation	+	+	+	+
1 min after the introduction of the cement into the acetabulum				
10 min after Step 3				
Before introduction of the cement and/or the prosthesis into the femur				
1 min after the introduction of the cement and/or the prosthesis into the femur				
10 min after Step 3				
20 min after Step 6				
30 min after Step 6				

centration (PaO_2), the arterial CO_2 concentration (PaCO_2) and to monitor the blood pressure (BP) and pulse continuously (EMT 34 Elema transducer + Mingograf 81 recorder). PaO_2 and PaCO_2 were measured directly by means of membrane electrodes (macrotechnique ILPO2-20335, ILPCO2-20334 Instrumentation Laboratory 313).

The timing of arterial and venous samplings and the operative events are indicated in Table 2.

RESULTS

C'H50, C3 and C4 variations during total hip replacement, Moore arthroplasty without MMC and with MMC (Figures 1-5)

The modifications of C'H50, C3 and C4 can be related to the two phases of the procedure.

Phase I Induction of the anaesthesia (samples 1, 2). The serum concentrations of C'H50, C3 and C4 were significantly decreased after the induction of the anaesthesia. The effect extended slightly into the first stage of the operation.

Phase II Surgery (samples 3 to 9). During surgery we observed a stabilization of C'H50, C3 and C4. During total hip surgery there was a slight but not significant decrease of

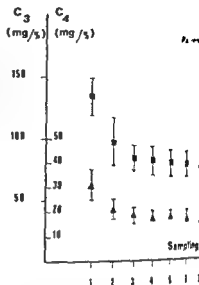


Figure 2 Variations of components 3 (C3) and 4 (C4) during total hip replacement (THA).

C'H50 after the introduction of the prosthesis into the femur (samples 6, 7).

Blood pressure and pulse (Table 3)

No modification of blood pressure were recorded during cementing acetabulum with MMC. After the implantation of the femoral prosthesis a decrease in

Total Complement

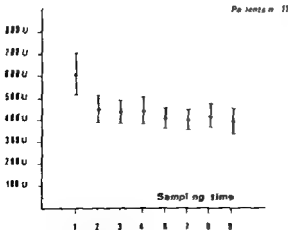


Figure 1 Variations of total haemolytic complement (C'H50) during total hip replacement (THA).

Total Complement

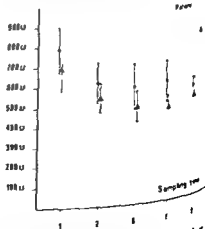


Figure 3 Variations of total haemolytic complement (C'H50) during cemented arthroplasty (CHP) and non-cemented arthroplasty (NCHP).

3 Blood pressure changes after introduction of the cement and/or the prosthesis into the femur

Type of operation	Blood pressure				
	Total	Elevation		Drop	
		>20%	>10%	>20%	>10%
hip arthroplasty	11	1	2	3	1
non-cemented hemi arthroplasty	7	—	2	1	—
cemented hemi arthroplasty	7	—	—	1	—
					Minor change
					(36.4%)
					4
					57%
					6
					(86%)
	25	1	4	5	1
		(4%)	(16%)	(20%)	(4%)
					14
					(56%)

ure equal to or greater than 20 per cent observed in five patients (20 per cent). In patients (56 per cent) the variation was less than 10 per cent. After impaction of the prosthesis we noted an increase in the blood pressure greater than 20 per cent in one patient (4 per cent) and a decrease of more than 20 per cent in three patients (12 per cent).

and PaCO_2 variations

1 minute after fixation of the femoral prosthesis a decrease in PaO_2 of more than 10 mmHg was registered in eight patients (32 per cent) and an increase in PaCO_2 greater than 10 per cent was noted in five patients (20 per cent).

DISCUSSION

The possibility of an abnormal sensitivity to MMC during orthopaedic surgery has been suggested by Kepes et al. (1972) who observed sudden death just after fixation of the femoral prosthesis with MMC.

Neither the surgery nor the introduction of the MMC affected the complement system in

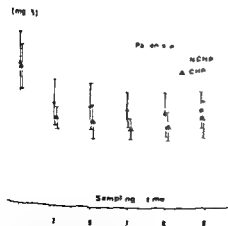


Figure 4 Variations of component 3 (C3) during cemented hemi-arthroplasty (CHP) and non-cemented hemi-arthroplasty (NCHP)

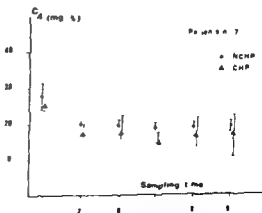


Figure 5 Variations of component 4 (C4) during cemented hemi-arthroplasty (CHP) and non-cemented hemi-arthroplasty (NCHP)

the 25 patients undergoing hip surgery. After recording a significant decrease of C'H50, C3 and C4 serum concentrations during the induction of the anaesthesia, we noted a stabilization of the CS during the surgical procedure. This emphasizes the importance of the interaction and the method of administration of the anaesthetic drugs on the CS. No relation could be found between the cardiovascular reactions and the CS variations observed. In our series 20 per cent of the patients presented a BP decrease in excess of 20 per cent. Parallel to this BP decrease no drop in the C'H50, C3 and C4 serum concentrations was recorded. Furthermore, the CS showed no significant changes during Moore arthroplasty with (CHP) or without (NCHP) the use of MMC.

The minor, statistically insignificant diminution of the CS components registered throughout the operation could be attributed exclusively to the effect of anaesthesia (repeated injections of drugs, plasma substitutes and transfusion). Haemodilution is not responsible for the initial drop of C'H50, C3 and C4 serum concentrations because all the patients received about 200 cm³ of 5 per cent glucose solution during the induction of the anaesthesia which represents less than 5 per cent of the blood volume. The reduction of the serum concentration in C'H50, C3 and C4 observed in the induction phase results very likely from an activation of the complement system. Indeed this observation cannot be explained by a haemodilution (as explained above) nor by a non-specific hypercatabolism.

CONCLUSION

The study of the complement system during endoprosthesis fixation with methylmethacrylate cement allows two conclusions to be drawn:

- 1 After an important activation of the complement system during the induction of the anaesthesia with flunitrazepam, fentanyl and pancuronium, surgery does not modify the complement significantly.

- 2 The introduction of the cement does not induce an activation of the complement system. This is an immunological process itself but is involved in some of the cardiovascular phenomena occurring during hip arthroplasty. MMC is not responsible for the activation of the complement system.

ACKNOWLEDGEMENTS

We wish to thank the Orthopaedic Dept (Prof de Marneffe) of the Brugmann University Hospital for allowing us to study patients in their care.

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EXPERIENCES WITH TOTAL HIP REPLACEMENT ARTHROPLASTY *AD MODUM* RING

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The results of total replacement of the hip joint *ad modum* Ring are presented. The review includes 63 hips (from among the total number operated by the various methods) followed up for periods ranging from 1 to 10 years. Excellent results in 37 hips.

Key words: Ring total hip prosthesis hip joint

Accepted 5 x 77

Total replacements of the hip joint *ad modum* Ring (Ring 1968, 1970, 1971, 1973, 1974) have been performed at the Orthopaedic Hospital, Medical Faculty, University of Zagreb, since 1970. It was decided to use Ring's prosthesis, because it seemed well biomechanically and did not involve the use of cement. It should be emphasized that the indications for total replacement of the hip joint have been extremely conservative. It has been used only in cases when no other type of surgery could be expected to offer better results with regard to the local alterations in the hip joint, the patient's age and profession.

(modified from the evaluation of results of Ring)

Excellent results in this evaluation are completely stable and painless hips with a range of flexion over 90° and corresponding abduction and rotation.

Table 1 Sex and side distribution

	Right	Left	Bilateral	Total
Female	19	21	2	42
Male	7	12	2	21
Total	26	41	37	104

Table 2 Hip disorders

	Number of hips	Percentage
Osteoarthritis	44	42
Congenital dislocation	7	7
Rheumatoid arthritis	4	4
Ankylosing spondylitis	4	4
Femoral head necrosis	3	3
Injury	1	1
Total	63	100

PATIENTS AND METHODS

Sixty-three operations on 59 patients were carried out (Table 1).

The disorders causing the hip alterations are shown in Table 2 and the age distribution of the patients (the majority were between 60 and 70) is given in Figure 1.

The assessment of the results is based on the usual three main factors: stability of the hip during walking, pain, and range of movement.

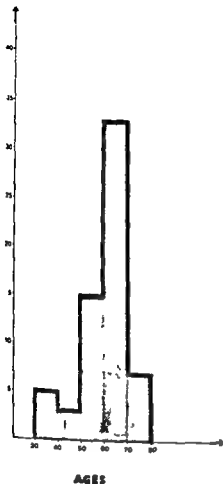


Figure 1 Age distribution

results included those patients who had to use one stick when walking and intermittent moderate pain or continuous pain. The flexion of the hip was between 90° while other movements were not restricted.

results included patients who had to use a short crutch and had moderate pain all the time and whose flexion ranged between 30° and 90° , while their other movements were not restricted.

results included those patients who were able to walk without crutches, had constant and no pain, and their range of all hip movements was good, flexion being less than 30° . All patients have been checked at 3- to 6-month intervals after the operation, and the follow-up examinations are continued from 6 months to 5 years after the operation (3).

Table 3 Period of review

Years	Number of hips	Percentage
1/2-2	17	26.9
2-3	20	31.8
3-4	11	9.5
4-5	20	31.8
Total	63	100

RESULTS

The results of the operations graded according to the above evaluation are shown in Table 4.

Complications

There were no complications at surgery, there was no dislocation of the prosthesis, bone fracture, or lesion of the sciatic nerve.

Among late complications there were three cases of instability of the prosthesis as a result of infection and two patients developed loosening of the prosthesis without evidence of infection. The prosthesis had to be removed in the three cases of infection because of functional and subjective complaints. Arthrodesis was carried out in one case and a Girdlestone operation in two cases.

In order to prevent infection Keflin has been administered according to an agreed schedule, since 1973, i.e., in the 24 most recent cases. None of these developed infection. Anticoagulants have been given in all cases with previous thrombosis or with

Table 4 Results

Grading	Number of hips	Percentage
Excellent	21	33.3
Good	32	50.8
Fair	11	9.5
Poor	4	6.4
Total	63	100

marked varicose veins of the lower extremities

Migration of the prosthesis occurred in one case of infection and in one case of bilateral replacement where the patient had ankylosing spondylitis. In some cases a radiolucent zone around the acetabular stem of the prosthesis was noticed. This zone, about 1 mm in diameter, was surrounded by denser bone and is probably a layer of fibrous tissue. This so-called halo effect was not linked with subjective symptoms in the majority of cases. Para-articular calcifications when present did not cause subjective complaints either, but the range of movement was somewhat restricted.

DISCUSSION

In the authors' experience preliminary results of the application of Ring's prosthesis were satisfactory provided the indications for the operation were strictly adhered to and the operative technique was of a high standard.

As in all other total replacements of the hip joint performed in this hospital i.e., *ad modum* McKee-Farrar and St. George, the results have been very conservative. Ring's prosthesis has been applied mainly in patients without marked osteoporosis who were expected to perform heavy work post-operatively.

As regards the surgical technique it can be added that it is more difficult to perform than other methods of total replacement of the hip particularly as regards the exposure of the acetabular part of the prosthesis. The altered position and shape of the acetabulum could present difficulties in orientation especially when inserting the stem of the femoral component. In our opinion full weight bearing should not be introduced until 3 months after surgery. In most cases an earlier weight bearing signs of pelvic instability with a positive *Duchenne* Trendelenburg's symptom occurred and this was regarded as an undesirable result of the reflexive unburdening of the hip.

We have noticed that the results tend to deteriorate in the course of time.

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DEMONSTRATION OF ROTATORY INSTABILITY IN INJURED KNEES BY STRESS RADIOGRAPHY

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Rotatory instability of injured knees may be demonstrated by stress radiography by recording the different movements of the medial and lateral tibial condyle on pull or push with the knee in 90 degrees flexion. The displacements of the condyles are expressed in millimetres, not degrees. Comparison with the healthy knee is always used. The displacement of a tibial condyle has to exceed 30 mm in relation to the healthy knee to be defined as pathological. If the movements of both condyles exceed the movements in the healthy knee by more than 30 mm in the same direction a drawer sign is present - if only one of them moves, an abnormal rotation is present. When a drawer sign is present there may still be a greater displacement of one of the tibial condyles which means a rotatory instability added to the drawer sign, designated a complex rotatory instability. All types of rotatory instabilities, simple and complex, are defined and discussed, in relation to the classification of Nicholas, Trickey and Slooem & Larson. Forty-one cases of abnormal rotation were demonstrated in this series by stress radiography. The direction of rotation and the type of instability are described and compared with the operative findings. The findings are in agreement with those of the above-mentioned authors and the experimental work of Warren et al.

Key words: complex instability, goniolaxometry, knee rotatory instability, complex, simple, stress radiography

Accepted 12.x.77

(1853) was the first to measure the rotation in healthy knee joints of living human beings. The measurements were made at 30 degrees of knee flexion, using a ruler on the sole of the foot, the ankle joint immobilized by a tight bandage. Ross in 1912 published a thorough study of 100 subjects with healthy knee joints, also using an externally placed ruler and measuring in degrees. Ouellet et al. (1969) have suggested a method for investigation of rotatory stability in 90° flexed knee joints by means of

measurements on serial radiographs. In this method the measured distances on the radiographs are transformed (by a cosine relationship) to degrees of rotation. As this method presumes a knowledge of the centre of rotation, only an approximate calculation is possible and furthermore it is only practicable in the healthy knee, while in the injured knee, in which the centre shifts to an unknown position, it is of no value. So far there have been no publications of measurements of rotation in injured knee joints. It is the

marked varicose veins of the lower extremities.

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As regards the surgical technique, it should be added that it is more difficult to perform than other methods of total replacement of the hip, particularly as regards the preparation of the acetabular part of the prosthesis. The altered position and shape of the acetabulum could present difficulties in orientation, especially when inserting the stem of the acetabular component. In our opinion full weight bearing should not be introduced until 3-6 months after surgery. In most cases earlier weight bearing signs of joint instability with a positive Dick Trendelenburg's symptom occurred and was regarded as an undesirable reaction to the reflexive unburdening of the hip.

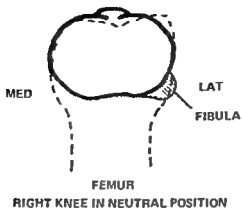
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COMPLEX ROTATORY INSTABILITY



purpose of this paper to show that gonylaxometry (Jacobsen 1976) offers a practical possibility for obtaining such measurements.

Definitions

In this paper internal and external rotation refer to the movement of the tibia in relation to the fixed femur. *Internal rotation* means that the tibial tuberosity rotates medially, the posterior parts of the tibial condyles moving laterally around an axis in the direction of the tibial shaft. *External rotation* indicates the reverse movement.

Medial instability (or valgus laxity) is defined as a movement in the frontal plane by which the knee joint is opened medially to a greater extent than normally. The patient's uninjured knee is used for comparison. In the gonylaxometer the measurement is done in 20 degrees knee flexion (angle between thigh and lower leg 160 degrees). The medial gap on the film is used as defined (Jacobsen 1976).

Lateral instability is defined analogously.

Drawer signs are defined as contemporary antero-posterior displacements of both tibial condyles in relation to the respective femoral condyles. The knees are flexed 90 degrees, the pointing straight forwards and parallel to the direction of the pulling or pushing force. In gonylaxometry a certain critical level of anterior or posterior displacement must be exceeded to establish a drawer sign as distinct from a normal antero-posterior displacement (a mean value exceeding 3.0 mm is used as a critical level, Jacobsen 1977).

Rotatory instability is defined in accordance with the remarks on internal or external rotation. It is measured in the gonylaxometer in 90 degrees knee flexion using the same method and stress forces as when measuring drawer signs. The term *simple rotatory instability* is used in circumstances where only the movement of one tibial condyle exceeds the critical level (no drawer sign present), in *complex rotatory instability* the movement of both tibial condyles exceeds the critical level but the one moves further than the other, which means a rotation in addition to a drawer

sign. The diagram of the different complex rotatory instability is given in Figure 1. The direction of the movement cannot be deduced from the diagram of the different types of instability as a classification. The names are derived from unstable structures. For example, in medial complex rotatory instability the name comes from the injured anterior cruciate and medial ligaments. The direction of the movement is external. From this it follows that the same instabilities as well as medial, lateral and antero-posterior instabilities are measured in millimetres and not converted into degrees.

METHOD

From gonylaxometry measurements on 100 subjects in a neutral position it can be seen that when a straight pull in the anterior direction is applied to the upper end of the tibia the displacement of the medial and lateral condyles is of different amplitude. The anterior displacement of the medial condyle is 2.3 mm (rounded off 2 mm) in 34 subjects and the mean for the lateral condyle is 4.4 mm (4 mm) or nearly twice as much as the medial condyle means an internal rotation of the tibia as shown in Figure 2. When an opposite force is applied, the posterior displacement in the normal knee is found to be nearly twice as much on the lateral condyle as on the medial (mean values 11.7 mm external rotation takes place).

If any abnormal rotation is to be detected the method of choice is to compare the parameters of the patient's healthy and injured knee. In the following all instabilities measured are defined as "movement in the injured knee minus movement in the healthy knee". The 95 per cent upper confidence limit of the difference between the two knees of a healthy subject for the above-mentioned parameters (anterior or posterior displacement of each condyle) is about 3 mm and ranges from 2.5 to 3.1 mm. A critical level of 3.0 mm is chosen for practical clinical use. A displacement of a tibial condyle less than this critical level to be defined pathological if the condyles move beyond this level in the same direction a drawer sign is present. If each of the condyles moves enough to exceed this level abnormal rotation must be present. The following criteria for a positive finding of rotatory instability are suggested: (a) the rotating condyle is displaced minimally 3.0 mm and (b) the

position with the feet fastened in 15 degrees external rotation it should be positive. Subsequent surgical operation would then show intact cruciate ligaments, intact lateral menisci and injury in the medial collateral ligaments alone. Two such cases were found in group 2. Both of them showed a mean anterior displacement of the tibial condyles of 4.4 mm in the position with 15 degrees external rotation of the feet. Furthermore in one of them with 30 degrees external rotation of the feet there was an anterior displacement of 3.2 mm. Thus stress radiography demonstrated a positive Slocum & Larson test. The menisci were intact in both patients. A conditionally simple rotatory instability may be demonstrated by stress radiographical measurements in the neutral position of the foot. In a case the medial tibial condyle at pulling from 'neutral position 90 degrees' showed 3.2 mm (criterion a) which exceeded the movement of the lateral condyle by 2.1 mm (criterion b) which shows external rotation, the mean of the two condylar movements (2.2 mm) did not exceed the normal level of 3.0 mm for anterior drawer test. With the feet fastened in 15 degrees external rotation the difference between medial and lateral condylar movement was greater. Intact menisci were found at operation. These three cases from group 2 had no scar tissue after rupture of medial ligaments. A further seven simple medial rotatory instabilities from group 1 and two from group 3 are shown in Table 1 and Figures 3 and 4, making a total of 12 cases. A simple lateral rotatory instability was found in two cases. A complex rotatory instabilities of all the types shown in Figure 1 were found in 25 cases in 24 knees antero-medial in 19 cases (Table 2). The pathoanatomy in all these cases consisted of anterior cruciate ligament rupture combined with medial collateral ligament rupture. This was clearly visible in group 1 and less obvious in the other groups where scar tissue had developed at the site of the medial structures. Antero-medial complex rotatory instability

was demonstrated by gonylaxometry in three cases. One case is shown in Figure 5. In the second case anterior drawer (7.7 mm) was found coupled with a posterior drawer (18.5 mm) and postero-medial instability at push (difference between posterior displacement of the tibial condyles 2.1 mm). Subsequent operation showed total rupture of both cruciate ligaments, the medial collateral ligaments and the capsule, as well as the postero-medial part of the capsule. The third case with total rupture of the medial structures and posterior cruciate ligament showed external rotation at pull and posterior drawer sign at push.

In one case combined antero-lateral and postero-lateral complex rotatory instability was demonstrated. The findings at operation were total rupture of the anterior and posterior cruciate ligament, lateral collateral ligament, popliteus and biceps femoris tendons, posterior and lateral capsule and partial rupture of the iliotibial tract and the medial collateral ligament. In another case of postero-lateral complex rotatory instability the operative findings were total rupture of the posterior cruciate ligament and the lateral collateral ligament.

In six patients external rotation in the injured knee occurred in the unloaded knee during rotation of the foot from the neutral to the 15 degrees externally rotated position. Only two of them were not further rotated by stress (external rotation - medial instability). The same criteria of rotation were used as in loaded knees.

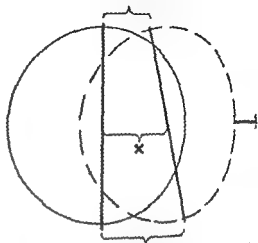
Totally 41 instances of abnormal rotation in 40 knees were shown by stress radiography in the series.

DISCUSSION

Slocum & Larson (1968) describe the clinical test position "with the foot and leg in 15 degrees external rotation". This has caused some practical difficulty, as the head of the tibia rotates less than half the rotation of the foot. Nevertheless the position of 15 degrees

Figure 2 Tibial head (right, seen from above) diagrammatically shown as a circle. During application of a pulling force (arrow) the medial condyle moves less than the lateral. On the radiograph straight linear distances are measured to represent the movement of each condyle. The landmarks used for the measurements are on the posterior part of the circle but in the same way points on the middle of the medial and lateral sides move. A chord at the posterior part of the circle, through the landmarks, will move parallel to the diameter shown and thus show the same angle of rotation. The movement of the centre shows the anterior displacement. The diagram may represent a normal knee if the braces represent the total movement in a normal knee. On the other hand it may represent complex rotatory instability, if the braces represent differences between an injured and a healthy knee of the same patient.

Anterior displacement of medial condyle



Anterior displacement of lateral condyle

x = displacement of centre

condyles of the injured knee are displaced to some degree the difference between the two condyles must exceed 2.0 mm (2 SD in healthy knees).

If both condyles can be displaced more than 0 mm and added to this one condylar displacement exceeds the other by 2.0 mm a drawer sign plus a rotation is present or in other words a complex rotatory instability exists (refer to Figure 2 and its legend).

Rotatory movements were studied both in the normal position for examination for drawer sign 'neutral position 90 degrees' with the feet pointing straight anteriorly and in positions with the feet externally or internally rotated 15 degrees and 30 degrees. The fastening gear may also be fixed in these positions in the goniometer.

PATIENTS

The material comprises 153 injured knees, 90 were examined 2 weeks or less after the injury (group 1), 26 from 15 days to 3 months after the injury (group 2) and in 37 a period of more than 3 months had elapsed since injury (group 3). For further details of the material, the various pathoanatomical features, medial and lateral instability, drawer signs, etc. refer to Jacobsen (1977). In many cases small differences in antero-posterior displacement

of the medial and lateral condyles of the knee not exceeding the above defined levels, were found radiographically. These are discussed further in this report. Measurements with the feet in 15 and 30 degrees rotation mentioned above were carried out in 61 cases.

FINDINGS

Simple rotatory instability may be demonstrated in two different ways. First the test of Slovicum & Larson (1968) may be performed with the feet fixed in 15 degrees external rotation and the knees fixed to 90 degrees in the goniometer. Prior to this fixation of the lateral collateral ligaments as described by Slovicum & Larson and a test for rotatory stability at stress radiography are performed. If an external rotation is to be demonstrated as a result of injury to the medial collateral ligaments alone the following criteria are fulfilled: provided the lateral collateral ligament is intact an anterior drawer test at position in neutral position must be negative.



Fig 3 Operative findings in case no 1 Isolated partial rupture of the superficial medial collateral ligament—long anterior fibres ruptured. In postoperative view of the knee joint, the long anterior fibres of the superficial medial collateral ligament are shown.

Fig 4 Isolated rupture of medial structures—superficial and deep medial collateral as well as oblique anterior ligament and medial capsule. Simple medial rotatory instability.

CASE 125



ISOLATED MEDIAL RUPTURE

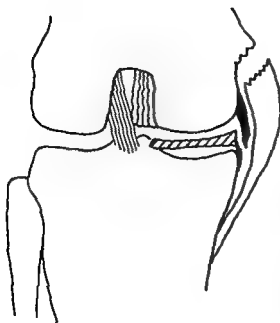
GONYLAXOMETRY

MEDIAL LOOSENESS 4 mm
ANTERO-POSTERIOR DISPLACEMENTS
IN NEUTRAL POS

ANT DISPL LAT CONDYLE	1.2 mm
ANT DISPL MED CONDYLE	3.0 mm
POST DISPL LAT CONDYLE	0.5 mm
POST DISPL MED CONDYLE	3.0 mm
ANT DRAWER (L 5-neg)	
POST DRAWER (L 8-neg)	
TOTAL ANT-POST DISPL LAT COND	2.5
TOTAL ANT-POST DISPL MED COND	6.0

WITH FOOT 15° OUTW. ROTATED THIS IS INCREASED TO 7.1

Fig 4 Isolated rupture of medial structures—superficial and deep medial collateral as well as oblique anterior ligament and medial capsule. Simple medial rotatory instability.



STRESS RADIOGRAPHY
 MEDIAL LOOSENESS 8.6 mm
 LATERAL LOOSENESS 10.5 mm
 POSTERIOR DRAWER MED COND
 LAT -
 BOTH CONDYLES MEAN

BOTH TIBIAL CONDYLES ARE DISPLACED
 BEYOND THE NORMAL LIMIT BUT THE
 CONDYLE BY FAR THE MOST

OPERATION TOTAL RUPTURE OF
 POST CRUCIATE LIGAMENT
 MEDIAL COLLATERAL SUPERFIC.
 MEDIAL COLLATERAL DEEP
 MEDIAL COLLATERAL OBLIQUE
 MEDIAL AND POSTERO MEDIAL
 CAPSULE

Figure 5 Recent injury Case no 89 Postero-medial complex rotatory instability (posterior & rotation)

Table 2 Examples of antero medial complex instabilities Measured in mm.

Pt no	Medial instability	Ant displ med cond	Ant displ lat cond	Difference = measure of rot	Ant. displ. (mean of med. and lat. cond.)	Meniscus injury
71	9.3	neutr 18.7	13.4	5.3	16.1	none
80	12.7	neutr 7.8	7.6	0.2	7.7	none
		15° ext 16.8	13.3	3.5	15.2	
84	4.8	neutr 5.4	2.2	3.2	3.8	none
		15° ext 5.9	2.8	3.1	4.4	
85	9.1	neutr 13.9	10.2	3.7	12.1	medial
115	none	neutr 3.6	0.9	2.7	2.3 (none)	both menisci and lateral removed rather
		15° ext 6.2	3.1	3.1	4.7	
116	5.9	neutr 8.4	6.3	2.1	7.4	none
		15° ext 7.9	4.9	3.0	6.4	
		30° int 3.7	2.4	1.3	3.1	
129	none	neutr 7.2	3.3	3.9	5.3	med + lat
130	none	neutr 8.5	4.4	4.1	6.5	med
133	none (1.9)	neutr 12.1	8.7	3.4	10.4	med meniscus removed

The difference between the movement of the two tibial condyles is calculated in column 5 - column 6 = difference in column six

mal rotation of the foot was chosen as a standard position, when examining for rotatory instability *ad modum* Slocum & Larson but in nine cases the knee was tested with the foot fixed in 30 degrees external rotation (which forces the proximal end of the tibia closer to 15 degrees external rotation as measured by an externally fixed pointer) As a result from the first mentioned cases with complete medial rotatory instability the latter position may give an even better outcome of the test in favour of the theory of Slocum & Larson.

In case no 78 with operatively proven complete rupture of the medial collateral ligaments and the anterior cruciate ligament, external rotation was shown with the foot in the neutral position, but a great increase of the anterior displacement with the foot in the 15 degrees externally rotated position gave evidence of medial rotatory instability. When the tibial condyles are rotated externally the fibular insertions of the lateral structures move posteriorly and, therefore, allow a greater anterior movement at pull even when restricted. This movement, prevented when the collateral ligaments are undamaged, occurs when they are damaged and to a still greater degree when the anterior cruciate ligament is ruptured also (still in agreement with the theory of Slocum & Larson).

Inter-medial instability was shown by Trickey (personal communication 1976) on lax knees with totally cut medial collateral ligaments and intact cruciate ligaments, with the knee flexed 30 degrees, as combined medial and external rotation. The present author agrees with this point of view, but prefers to analyse each of these movements (gap in frontal plane and rotation) separately.

In the case in Figure 4 nature has produced an injury so "clear cut" that it may easily be reproduced experimentally on knee specimens. In such a specimen Trickey demonstrated his inter-medial instability. With the methods and definitions used by the present author it is possible to demonstrate both medial instability in the frontal plane in this case and

external rotation (anterior displacement of the medial tibial condyle at 90 degrees knee flexion and pull) and internal rotation (posterior displacement of medial condyle at push) due to instability of the medial structures alone.

Rotatory instability at gonylaxometry was only demonstrated in cases where operation disclosed a total rupture of the long anterior fibres of the superficial medial collateral ligament, the exact pathoanatomy being only accessible in the recent injuries and a few other cases (as in Figure 4) with non union and scanty scar tissue formation. No rotation exceeding the critical levels of the criteria were shown in injuries comprising only the deep and oblique posterior medial collateral ligaments. This is in agreement with Warren et al (1974, p 671 and charts IV and V) who write "relatively large increments in both medial joint space opening (valgus) and rotation are allowed by releasing the long fibres in an otherwise intact specimen. Conversely, cutting the deep ligament produces almost no change if the long fibres are intact".

As the middle and posterior fibres of the superficial medial collateral ligament are taut in extension and slight flexion but slack and inverted anteriorly in 90 degrees knee flexion [refer to Lanz & Wachsmuth (1938) p 233, Abb 188 or Warren et al (1974) p 666], and the anterior fibres behave in the opposite way (slack in extension and taut in 90 degrees flexion) findings like those in case no 1 (Table 1 and Figure 3) may occur. The middle and posterior fibres, intact in this case, prevent medial instability, when measured in 20 degree knee flexion (the 160 degrees position) as in the gonylaxometer. In the 90 degrees position in which they are slack and anteverted they allow anterior displacement of the medial tibial condyle — or external rotation. This movement should have been prevented by the anterior fibres of this ligament, but they have ruptured in this case. The injury was sustained in a skiing accident during flexion and external rotation of the knee. The same occurred in case no 2.

Complex instability was def

classified by Nicholas (1973) as contemporary instability in two or more planes. Referring to this definition Trickey's antero-medial instability is a kind of complex instability. The author of this article prefers to use the term complex instability only in connection with rotatory instability. Within this concept the terminology is defined in full agreement with Nicholas' nomenclature. Lastly attention must be drawn to the measuring technique with a force acting which tightens the intact structures. The rotation produced in this way is probably less than if a rotating force were applied directly with the knee in the neutral position (no antero-posterior stress on the ligaments). Some findings indicate this. In case no 150 the feet were also rotated externally 30 degrees and then tested for anterior displacement—and no movement at all of the medial condyle was found. But unloaded the medial condyle had moved 7.4 mm more than the lateral from neutral position to the position with 30 degrees externally rotated feet, i.e., the rotation had taken place already before the pulling force was applied to the rotated leg. Such rotation of the unloaded knee was found in another five cases, but only two did not move further on.

It may be concluded that rotatory instability of the knee—simple, medial and lateral, as well as all the complex types discussed theoretically and the antero-medial type shown clinically by Nicholas—can be demonstrated and measured by stress radiography in a clinical material of injured knees. The findings are in agreement with the experimental work of Warren et al (1974).

ACKNOWLEDGEMENTS

Aided by grants from the Danish Medical Research Council, the Danish Council for Sports Injuries and the Foundation for the Handicapped.

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PSEUDOCHONDROMALACIA PATELLAE

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A condition causing knee pain with retropatellar crepitus similar to chondromalacia patellae is described. The symptoms seem to be due not to chondromalacia of the patella, but to a local synovial thickening proximal to the articular surface of the medial femoral condyle. Thirteen patients, aged 10 to 21 years, were operated upon because of this condition, three of them bilaterally. In most of them the changed synovial membrane was excised. The operation in eleven of the knees was followed by considerable or complete relief. Of the remaining five knees, three were temporarily improved.

Key words: pseudochondromalacia patellae, chondromalacia patellae, knee joint, synovitis

Accepted 11.x.77

gle (1972) and Smulhe (1974) have described a condition with knee pain caused by thickening of the synovial membrane localized to the anterior articular surface just proximal to the articular surface. Both authors stress that the condition can be mistaken for chondromalacia patellae. Smulhe called the condition "pseudochondromalacia of the patella". This report seems to confirm Nangle's and Smulhe's observations.

PATIENTS

The material consisted of thirteen patients, six males and seven females. Three of the females were operated upon bilaterally. The patients' ages at the time of operation ranged from 10 to 21 years (mean 15 years) (Table 1). The patients presented for treatment over a period of 3 years at an orthopaedic department serving a population of 100,000 inhabitants. During the same period chondromalacia patellae was diagnosed in a much smaller number of cases.

Symptoms

The duration of symptoms varied between 6 months and 5 years, in most cases more than 2 years. All of the patients denied any known trauma. The condition was not related to any particular type of physical activity.

All the patients reported knee pain when walking or running. The pain was localized to the anterior part and sometimes also to the inside of the knee. The pain became more pronounced on exertion. After exertion the pain was often felt for some hours even at rest. None had any history indicating luxation or subluxation of the patella. Spontaneous pain at rest was common. Most of the patients had a feeling of crepitations in the knee and several had experienced a sensation of momentary catching but not actually locking. None had noticed any swelling of the knee. Nine had bilateral symptoms. In three of them both knees were operated upon while in the remaining six the symptoms in the other knee were not considered severe enough to warrant operation. For further details concerning the symptoms see Table 1.

None of the patients had any manifestations of generalized joint disease or other systemic illness at the time of operation. However, later one of the patients developed symptoms in other joints, and he might possibly have rheumatoid arthritis.

Table 1 Clinical details (thirteen patients)

Age at operation (years)	Sex	Symptoms bilaterally	Side operated	Duration of symptoms (years)	Pain on motion	Pain at rest	Feeling of crepitations	Catching	Follow up time (years)	Postoperative results	Remarks
10	F	+	R	1	+			+	2.5	Improved	
13	M		R	3	+	+	+		2	Symptom free	
13	M		R	1	+	+			3	Symptom free	Partial chondrectomy of patella
14	M	+	R	1	+		+		2.5	Improved	
15	F	+	R	2	+		+		2	Symptom free	
16	F		L	2	+	+	+		1	Symptom free	
16	M	+	L	1.5	+		+		2	Not improved	Symptom free for 4 months postoperatively
17	F	+	L	2	+	+	+	+	1.5	Symptom free	
17	F	+	R	1	+	+	+	+	2	Improved	
18			L	3	+	+	+	+	0.5	Improved	Partial chondrectomy of patella
18	F	+	R	4	+	+		+	2.5	Symptom free	
19			L	5	+	+		+	1.5	Not improved	Symptom free for 3 months postoperatively
20	M	+	R	3	+		+		2.5	Not improved	Symptom free for 4 months postoperatively
20	M		R	0.5	+		+		2	Not improved	Rheumatoid arthritis?
20	F	+	L	0.5	+	+		+	2.5	Improved	
21			R	1	+	+	+		2	Not improved	Fracture of patella 3 weeks postoperatively

For cartilage of the patella joint of the patients who responded off for time limited. For all the patients a revision was performed.

With the knee extended translation of the patella medially or distally applying simultaneous pressure on the upper part of the patella invariably elicited painful crepitations. These crepitations included those which can be felt in chondromalacia patellae. All the knees were tender to palpation in an area covering 3-4 cm² on the anterior surface of the femur, immediately proximal to the articular surface of the medial femoral condyle (Figure 1). Palpation of this area revealed a rough, uneven surface. This part of the examination was best carried out with the knee flexed at 70-80°. The stability of all the knees was normal and none showed evidence of exudate. In all knees the position of the patella relative to the femoral condyles was judged as normal. In all the knees the mobility of the ankle, knee and hip was normal. Three patients could not squat with their heels flat on the ground. The E.S.R. was normal in all patients. A-P and lateral roentgenograms of the extended knee and lateral roentgenograms of the knee flexed about 30° were normal. In all knees in which the growth plate in the upper femur was closed before operation the relation

between the femoral condyle and the patella was normal. In the knees in which the growth plate in the upper femur was open and for technical reasons such measurement was not possible

OPERATIVE FINDINGS AND TREATMENT

The knee joint was explored via a medial parapatellar incision in a bloodless field with the patient under general anaesthesia. Immediately proximal to the articular surface of the medial femoral condyle the synovial membrane was found to be reddened and thickened. The site of the thickening corresponded to the area with tenderness and a palpable rough surface. On translation of the patella in a proximal direction over this area the synovial membrane folded in front of the upper cartilage-lined pole of the patella (Figure 2). On continued translation of the patella in a proximal direction the synovial cushion was forced under the patella. This occurred gradually and every time a portion of the membrane was pressed under the patella, the latter jerked. When this was repeated one experienced a sensation of crepitations in the hand manipulating the patella. The same thing happened when the patella was translated distally from its most proximal position. This finding corresponded to the retropatellar crepitations felt preoperatively.

The changed portion of the synovial membrane was excised together with the underlying fatty layer without interfering with the periosteum. Afterwards the crepitations could no longer be elicited.

In none of the cases was it possible to detect or feel any fissures or other changes in the cartilage of the patella or femoral condyles. The position of the patella relative to the femur was judged as normal. The amount of synovia was not increased. The menisci and the cruciate ligaments were normal in the parts that could be examined via the incision. The incision was closed in layers and the leg was immobilised in plaster from the groin to the ankle with the knee extended. The patient was allowed to walk on the leg as soon as he could. The plaster and the skin sutures were removed after 10-14 days. As a rule the patients recovered full mobility of the knee in 3-4 weeks.



Figure 1 The medial side of the knee. The hatched area is the site of tenderness to palpation and the area in which a rough uneven surface can be palpated.

Nangle and Smillie contended that the aetiology in their cases was patella alta this having caused an abnormal contact between the patella and femur. In the cases presented here it was necessary to search for another explanation. Primary synovitis localized to this particular area appears improbable. It appears more likely that the cause was a special configuration of the patella and/or femur or some abnormal pattern of movement between them. The fact that the two patients in whom the upper cartilage-lined margin of the patella was rounded off made an almost complete recovery although the thickened synovial membrane was left untouched argues for such a cause. However, owing to lack of precise knowledge of the normal configuration of this special part of the patella in this age group it is not possible to say whether the form of the patella was abnormal in the patients in this material. Nor could any abnormal shape of the femur or any abnormal pattern of movement between the patella and the femur be detected. However, the thickening and reddening of the synovial membrane was considered definitely pathologic in all the cases, for which reason this part of the membrane as a rule was excised.

In those patients in whom the symptoms recurred some time after the operation tenderness to palpation and the roughness

proximal to the medial femoral returned. This was ascribed to a recurrence of the thickening of the synovial membrane. It would have been interesting to reoperate these knees and then round off the cartilage-lined corner of the patella. This was not considered warranted until known about this condition.

ACKNOWLEDGEMENTS

Thanks are due to Thorbjørn Berge for the histologic examinations.

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LE FRACTURES TREATED BY FIXATION OF THE IAL MALLEOLUS ALONE

Results in 29 Patients

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A review of 29 patients with unstable ankle fractures treated by fixation of the medial malleolus alone is presented. At follow up the result in 16 patients was classified as unsatisfactory or a failure and all of these patients showed radiological signs of posttraumatic arthrosis deformans. The importance of the position of the lateral malleolus in order to prevent joint incongruity and subsequent arthrosis is emphasized.

Key words: ankle fractures, arthrosis

Accepted 28.xi.77

problems in orthopaedic surgery have received more attention than the treatment of displaced fractures of the ankle. Opinions as to the treatment of choice diverge widely, ranging from closed reduction (Kristensen 1956, Watson-Jones 1955) to rigid intramedullary internal fixation of almost every fracture as recommended by the A-O group (Renegger & Weber 1963, Weber 1966). In many years the position of the medial malleolus was considered a cardinal point and several authors have recommended operative reduction and fixation of the medial malleolus combined with closed reduction of the lateral malleolus (Muller 1945, McLaughlin & Ryder 1959). In cases with a posterior tibial fragment which comprised more than one quarter of the joint surface it was recommended that this be fixed separately. Until recently we have followed this principle and this paper presents the late results in 29 patients.

PATIENTS AND METHODS

In the 5 year period from 1969 to 1974 a total of 231 patients with displaced malleolar fractures were treated in our hospital. 126 patients were treated by closed reduction and 105 by operation. Forty three patients had only one fractured malleolus, while the remaining 62 patients were suffering from bi- or trimalleolar fractures. Of these 62 patients, 28 had only a posterior tibial fragment fixed and the material thus comprises 33 patients treated with screw fixation of the medial malleolus and closed reduction of the lateral malleolus.

In four cases a posterior tibial fragment of more than one quarter of the joint surface was fixed separately. At follow-up two patients had died, which left 31 patients. Two patients were unavailable so 29 patients were reviewed (94 per cent). The patients were asked to fill in a questionnaire concerning subjective symptoms, working ability and restrictions in sport. All patients were examined clinically and X-rays of the ankle were taken. The material consisted of 19 males and 10 females and the age distribution is shown in Figure 1. Only patients over 15 years

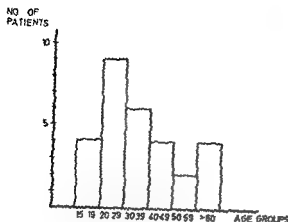


Figure 1 Age distribution of 29 patients with displaced fractures of the ankle

age were included, and the mean observation time was 4.6 years.

The material was obtained retrospectively.

RESULTS

The classification of the fractures was made according to Lauge Hansen (1942) and is shown in Table 1. The result was classified as follows:

Excellent No pain, no swelling, full or only negligible restriction of motion.

Reduced capacity for work

Unsatisfactory Pain on motion, swelling, reduced capacity for work necessitating a change to light work, considerable stiffness.

Failure Unable to work, daily pain, severe stiffness.

The overall results are shown in Table 2. More than half the results were either satisfactory or failures.

The degree of posttraumatic arthrosis determined radiographically is as follows:

Slight arthrosis Slight reduction of the space and slight formation of deposits in joint margins.

Moderate arthrosis Joint space reduced 50 per cent, sclerotic configuration with subchondral osseous tissue of the Moderate formation of deposits.

Severe arthrosis Joint space virtually nonexistent. Severe formation of deposits.

The degree of arthrosis is shown in Table 3. All patients demonstrated some arthrosis in the mild cases localized to lateral part of the ankle joint. The relationship between the degree of arthrosis and the result is shown in Table 4. It is seen that even a severe degree of arthrosis does not preclude a satisfactory result.

The result as related to the age of patient is demonstrated in Table 5. Seven of eight failures were patients under 30 years of age, while the excellent results were obtained in the older age groups. It is perhaps that the handicap is greater in younger, more active persons.

DISCUSSION

The objective of the treatment of ankle fractures is to achieve an anatomic satisfactory joint reconstruction.

Table 1 Classification of 29 ankle fractures according to Lauge Hansen (1942)

SUPINATION-OUTWARD ROTATION STAGE IV	21
PRONATION-OUTWARD ROTATION STAGE III-IV	6
SUPINATION STAGE II	2
TOTAL	29

Table 2 Overall late results in 29 patients

EXCELLENT	: 3	} 13
SATISFACTORY	: 10	
UNSATISFACTORY	: 8	} 16
FAILURE	: 8	

3 Degree of posttraumatic arthrosis deformans in 29 patients

LIGHT ARTHROSIS	: 14
MODERATE ARTHROSIS	: 8
SEVERE ARTHROSIS	: 7
TOTAL	: 29

4 The relation between late results and degree of arthrosis in 29 patients

LIGHT ARTHROSIS, 14 PATIENTS

EXCELLENT	: 3
SATISFACTORY	: 2
UNSATISFACTORY	: 5
FAILURE	: 4

MODERATE ARTHROSIS, 8 PATIENTS

EXCELLENT	: 0
SATISFACTORY	: 5
UNSATISFACTORY	: 1
FAILURE	: 2

SEVERE ARTHROSIS, 7 PATIENTS

EXCELLENT	: 0
SATISFACTORY	: 3
UNSATISFACTORY	: 2
FAILURE	: 2

Table 5 Mean age of the patients in relation to the late result

EXCELLENT	: MEAN AGE 43
SATISFACTORY	: MEAN AGE 32
UNSATISFACTORY	: MEAN AGE 32
FAILURE	: MEAN AGE 23

essential basis for optimal joint function and prevention of the development of arthrosis deformans (Cedell 1975). Many authors have shown that joint incongruity leads to arthrosis (Lewis & Graham 1940, Palmer 1941, 1944). Conservative treatment involving reduction and fixation in plaster is recommended by many surgeons (Kristensen 1949, 1956, Watson-Jones 1955, Kleiger 1961). They resort to operative treatment only in cases in which repeated attempts at reduction do not result in acceptable fracture position.

Others believe that fixation of the displaced medial malleolus and of a large posterior tibial fragment with subsequent reduction of the lateral malleolus is indicated (Muller 1945, McLaughlin & Ryder 1949).

However, many authors have pointed out that non-operative reduction of the lateral malleolus seldom results in an anatomically satisfactory joint reconstruction due to interposition of ligaments, cartilage, and bone fragments (Palmer 1950, Burwell & Charnley 1965, Weber 1966, Cedell 1967).

Breitenfelder (1957) and Willenegger (1961) have shown that widening of the ankle mortise due to even minute rotation and lateral displacement of the lateral malleolus results in a diminished contact area between the tibia and the talus. Lateral subluxation of the talus means that the exact fit between the articular ridge of the tibia and the corresponding articular groove of the talus is disturbed leading to incongruity and arthrosis (Cedell 1975). In all our patients the lateral malleolar fracture healed in a position with varying degree of outward rotation, lat

proximal, and dorsal displacement, and they all showed signs of arthrosis deformans.

The question is now whether operative treatment aiming at reconstructing all components of the ankle joint is superior to more conservative measures. Comparing Magnusson's conservatively treated material (1944) to his own treated by operation, Cedell (1967) found a reduction of the frequency of arthrosis deformans in supination-outward rotation injuries stage IV from 82 to 38 per cent. In the present series, comparable as regards age and sex of the patients, using the same classification of the fractures, a frequency of 100 per cent was noted.

The result in 16 out of 29 patients was classified as either unsatisfactory or a failure, but as the development of arthrosis deformans is a rather slow process (Hendelberg 1943), the mean observation time of 4.8 years makes a further reduction of the number of good results probable. The connection between arthrosis deformans and subjective symptoms has been discussed for many years. A mild degree of arthrosis is not necessarily accompanied by subjective symptoms (Magnusson 1944, Klossner 1962) but marked arthrosis nearly always involves severe subjective symptoms (Hendelberg 1943, Willenegger 1961, Klossner 1962).

This paper supports the view that exact reposition of the lateral malleolus is essential for good joint function and the prevention of the development of posttraumatic arthrosis deformans. It also shows that this position cannot be achieved by conservative measures, and we therefore recommend operative fixation of unstable malleolar fractures.

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ASYMMETRY OF PLANTAR FLEXION STRENGTH IN THE FOOT

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A study of plantar flexion strength and calf circumference in 30 conscripts is submitted. It showed an asymmetry of strength amounting to 6-11 per cent (95 per cent confidence limits). The right leg was significantly stronger than the left, but there was no difference in strength between the dominant and non-dominant leg. There was little correlation between circumference and strength.

Key words: foot, laterality, leg circumference, muscle contraction, muscular asymmetry, plantar flexion

Accepted 15 xi 77

Traumatic reduction of strength is to be expected, the degree of difference in strength between symmetrical muscle groups must be small (Heebell-Nielsen 1964), and it must be noted also whether dominant and non-dominant muscle groups differ in strength (Lissner & Chalmers 1970). Ergometric studies of normal limbs have demonstrated a relationship between maximum power and amount of effective muscle tissue (Davies & Jeant 1975). On clinical examination and follow-up studies, muscle strength has not been assessed by measuring circumference. According to theoretical considerations, however, there may be qualitative differences between normal muscles (Lissner & Christensen 1975) and little correlation has been demonstrated between circumference and isometric strength and aerobic endurance in previously injured limbs (Dahmolt & Zdravkovic 1972).

MATERIAL

To elucidate these aspects we studied the strength of plantar flexion in 30 new conscripts without

previous injuries to the lower limbs and with a fairly equal distribution of side dominance. The dominant leg is taken to mean the leg which the person prefers for jumping and/or for a forceful, accurate kick at a ball.

Table 1 presents age, height, and weight.

Table 1 Age, height, and weight distribution of 30 conscripts

	Max	Min	Mean
Age (years)	26	19	21.1
Height (cm)	193.5	166.0	179.3
Weight (kg)	94.2	60.1	72.7

As the dominant leg 20 stated the right and 10 the left leg.

METHOD

For measuring the plantar flexion strength of the foot we used an electronic strain-gauge dynamometer designed by Darcus (1953). The device for fastening the leg to it was designed by the present authors (Figure 1). When the leg is fastened in the unyielding apparatus, contraction of the calf muscles must be considered isometric. In the measurements the set-up was as reported by Amussen & Heebell-Nielsen (1961). The scale is

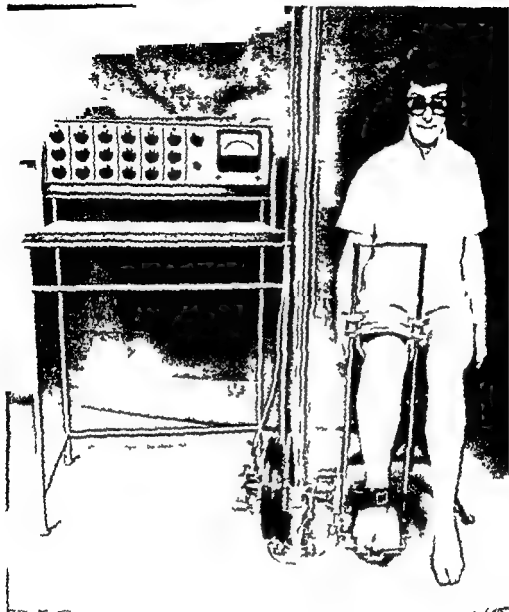


Figure 1 Darcus strain gauge dynamometer combined with the present authors device for force limb

calibrated so that the strength can be read directly in $\text{kg} \times \text{cm}$

The plantar flexion strength recorded was the maximum excursion on the scale that the subject could achieve at repeated measurements. The recorded circumference refers to the greatest calf circumference.

RESULTS

The ratio between strength in the right and left legs is apparent from Table 2. In 22 out

of 30 persons (73.3 per cent), the right leg was stronger than the left. The mean strength in the right leg was $1725 \text{ kg} \times \text{cm}$ and in the left leg 1630 , i.e. a difference of 95 . This difference is significant ($P < 0.01$).

Figure 2 gives the correlation between plantar flexion strength in the right and left leg. The correlation coefficient is 0.41 and the correlation is significant ($P < 0.05$). Similarly, Table 3 and Figure 3 give

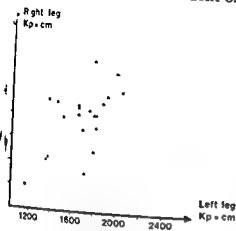


Figure 2 Correlation between plantar flexion strength in the right and left leg in 30 conscripts ($r=0.68$)

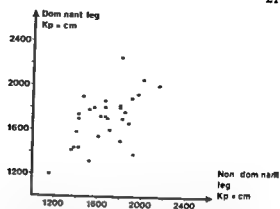


Figure 3 Correlation between plantar flexion strength of the dominant and non dominant leg in 30 conscripts ($r=0.60$)

between the dominant and non-dominant leg. The dominant leg had a mean strength of 1693 $\text{kp} \times \text{cm}$ as compared with 1666 $\text{kp} \times \text{cm}$ in the non-dominant leg a difference of 16 per cent which is not significant ($0.4 < P < 0.5$). The correlation between the strength in the dominant and non-dominant leg is significant ($r=0.60$, $P < 0.001$).

The correlation between strength in the stronger and weaker leg is illustrated in Figure 4. The correlation is significant ($P < 0.001$) and the correlation coefficient 0.80. The mean difference in strength between the weaker and stronger leg was 149 $\text{kp} \times \text{cm}$ or 8 per cent. The 95 per cent confidence limits were 97–201 $\text{kp} \times \text{cm}$ (or 6–11 per cent).

Figure 5 shows the relationship between

Table 2 Plantar flexion strength in the right and left leg of 30 conscripts

	Mean strength $\text{kp} \times \text{cm}$	S.D.	Range	Per cent of persons in whom the right leg was stronger	R/L in per cent of R
Right leg	1728	235	1200–2250	73.3 (22/30)	5.7
Left leg	1630	210	1160–2050		

Paired t test $t=2.989$ degrees of freedom 29 $0.005 < P < 0.01$

Table 3 Plantar flexion strength in the dominant leg (D) and non dominant leg (d) in 30 conscripts

	Mean strength $\text{kp} \times \text{cm}$	S.D.	Range	Per cent persons stronger in D	D-d in per cent of D
Dominant leg	1693	231	1200–2250	60.0 (18/30)	1.6
Non-dominant leg	1666	225	1160–2150		

Paired t test $t=0.7291$ degrees of freedom 29 $0.4 < P < 0.5$

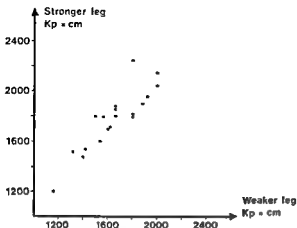


Figure 4 Correlation between plantar flexion strength in the stronger and weaker leg of 30 conscripts ($r = 0.80$)

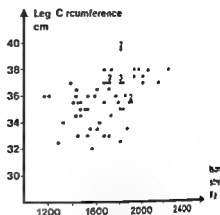


Figure 5 Correlation between calf circumference and plantar flexion strength in 30 conscripts ($r = 0.41$)

strength and circumference. There is a wide dispersion of the values, indicating little relationship between the two parameters. The correlation coefficient, $r = 0.41$, is correspondingly low, but the correlation is significant ($0.001 < P < 0.01$).

DISCUSSION

In a study of 96 conscripts Heebøll-Nielsen (1967) found that a difference in strength between symmetrical muscle groups of 10 per cent was not significant, but a difference of 20 per cent was. The present results of this investigation of plantar flexion strength in the feet of 30 conscripts confirm this finding, as there was a mean difference in strength between the weaker and stronger leg of 149 $\text{kp} \times \text{cm}$ or 8 per cent. The 95 per cent confidence limits were 97–201 $\text{kp} \times \text{cm}$ (or 6–11 per cent). Therefore, in dealing with sequelae to traumas affecting the lower limbs it is reasonable to interpret a difference in strength in calf muscles exceeding 15 per cent as pathological.

Gillies & Chalmers (1970), studying plantar flexion strength in eight normal persons, found that the dominant leg was an average of 15.8 per cent stronger than the non-dominant leg. With this background they in-

troduced a corresponding correction strength measurement in the following patients treated for rupture of the Achilles tendon. In our study the dominant leg was stronger in 60 per cent of the subjects; true, but the difference in strength was on average 27 $\text{kp} \times \text{cm}$ or 1.6 per cent. This difference is not significant ($0.4 < P < 0.5$).

On the other hand, the right leg was, on average, 5.7 per cent stronger than the left leg. This difference is significant. Even in a group in which the left leg was dominant the right leg was, on average, 5.6 per cent stronger than the left. In a follow-up study using measurements of strength following trauma to the limbs, in series with a marked difference in the number of right-sided and left-sided injuries, the difference in strength between the right and left leg demonstrated in the present investigation might also be a basis for correcting the strength measurements.

In two series of patients with a lower femoral fracture Damholt & Zander (1972, 1974) found low correlation ($r = 0.23$ and 0.27) for the relationship between circumference of the thigh and isometric quadriceps strength.

In the present study of normal persons there was a somewhat higher correlation coefficient ($r = 0.41$) for the relationship

mean calf circumference and isometric plantar flexion strength in the foot. Nevertheless, the circumference is a poor expression of muscle strength, as the coefficient of determination r^2 is only 0.17, meaning that variation in one parameter explains only 17 per cent of the variation in the other measured around the mean value.

Conclusion

A study of calf circumference and plantar flexion strength in a series of normal persons was conducted.

A variation of 6–11 per cent between the strength of symmetrical muscle groups (95 per cent confidence limits).

No statistically significant difference in strength between the dominant and non-dominant leg.

A significantly greater strength of the right than the left leg.

Little correlation between circumference and strength.

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OSTEOSARCOMA OF THE METATARSAL BONES

Review of the Literature and Report of a Case

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A case of osteosarcoma affecting the third metatarsal bone is described. Below knee amputation was performed, but the patient developed pulmonary metastases and died 1 year after the operation. The six cases of osteosarcoma in the metatarsal bones published so far are reviewed. The prognosis for patients with this localization does not appear to differ from that for osteosarcoma in general.

Key words: osteosarcoma, metatarsal bones

Accepted 11 x.77

In his book "Fractures and Joint Injuries" Watson-Jones (1960) said, speaking of the metatarsal bones, that "sarcoma of this bone has not yet been reported in thousands of years in any country". He thereby wanted to show how absurd an erroneous diagnosis of sarcoma is when march fractures are so common at this site and to stress the serious consequences that such a mistaken diagnosis may entail and has indeed entailed (Dodd 1933).

At any rate, osteosarcomas of the metatarsal bones are extremely rare. Reviewing the literature we found only six cases. However, this probably does not give a true impression of the incidence, as in many reports on osteosarcoma the exact site of the tumour is not stated. Table 1 lists the materials published so far in which the site has been sufficiently clearly elucidated. It will be seen that metatarsal osteosarcomas make up about 0.5 per cent of the total number of osteosarcomas on record. On the basis of the incidence of osteosarcomas in general (Coley 1949), this corresponds to an incidence of metatarsal osteosarcomas of one case in 20

Table 1 Occurrence of osteosarcoma of the metatarsal bones in the materials published. Only materials giving sufficient information on the exact location of the tumours are included in the Table

	Number of osteosarcomas	Metatarsal
Code (1955)	133	1
Coventry & Dahlin (1957)	430	2
Lindborn et al. (1961)	96	1
Lee & MacKenzie (1964)	160	2
McKenna (1966)	258	1
Maroove et al. (1970)	145	1
Jenkin et al. (1972)	62	1
Scranton et al. (1975)	54	1
Price et al. (1975)	125	1
Present material*	49	1
Total	1522	7

* Disting et al. (In press)

million people.

Among a 10-year material from 1973 we found out of 49 cases of osteosarcoma one which was localized to a metatarsal

E REPORT

On 15 March 1971 a 22-year-old imbecile man (U case rec. 20654) noticed a swelling on the inner side of his left foot. It caused mild pain and difficulty in wearing shoes. When he was first seen 18 months later there was a mass, "half the size of a fist", on the middle of the dorsum of the left foot. Radiography on May 10th showed a tumour of the third metatarsal bone (Figure 1). In spite of the radiological finding the tumour was diagnosed clinically as a benign osteochondroma, and in the hospital an *en bloc* non-radical excision of the tumour and the affected metatarsal bone was performed on June 24th. At the operation the tumour was found to be infiltrative, involving the surrounding soft tissues, especially in the sole. The surface of the removed tumour was yellowish

white and lobulated. Histological examination, as well as subsequent revision of the preparations, revealed a chondroblastic osteosarcoma (Figure 2). The patient was then referred to the Department of Orthopaedic Surgery, Rigshospitalet, University of Copenhagen, where he was admitted in July. At that time there were no signs of dissemination of the tumour, in particular the chest radiography was normal. On July 20th a below-knee amputation was carried out. The amputation specimen contained in the tumour a few small metastases.

same year

DISCUSSION

It is a fairly common assumption that osteosarcomas affecting the hand and foot have a relatively favourable prognosis (Coventry & Dahlin 1957). Since, however, these sites are extremely rare, the prognostic evaluation must be based upon the fact that in some materials the prognosis is better for tumours localized distally than proximally in the limbs. This is in accordance with the experience of Marcove et al. (1970) in whose material pulmonary metastases occurred fairly late when the tumours were localized distally to the knee and elbow. Moreover, Dahlin & Coventry (1967) and Jaffe (1958) found a better 5-year survival after tumours affecting the tibia than the femur. Jeffree et al. (1975) found relatively few extrapulmonary metastases from tumours in the tibia. Others (Stanley & MacKenzie 1964, Scranton et al. 1975) could not confirm this finding. In any case, the differences found are rather slight, and it was only in Dahlin & Coventry's material that the difference was statistically significant ($P < 0.01$).

However, if there is a relationship, viz., that a more peripheral site affords a better prognosis, metatarsal osteosarcomas would be expected to have a particularly long survival. Reports published so far have not provided any evidence of this kind. Coventry & Dahlin (1957) reported two patients with metatarsal osteosarcoma both of whom died within a



1 Radiography showing a chiefly osteolytic tumour involving the proximal two-thirds of the third metatarsal bone. In the large calcified soft component of the tumour a spicular pattern is seen in places.

OSTEOSARCOMA OF THE METATARSAL BONES

Review of the Literature and Report of a Case

O SNEPPEN, I DISSING, J HEERFORDT & T SCHIÖDT

Department of Orthopaedics and Department of Pathology, Rigshospitalet, University of Copenhagen and the Radium Centre, Finsen Institute, Copenhagen Denmark

A case of osteosarcoma affecting the third metatarsal bone is described. Below knee amputation was performed but the patient developed pulmonary metastases and died 1 year after the operation. The six cases of osteosarcoma in the metatarsal bones published so far are reviewed. The prognosis with this localization does not appear to differ from that for osteosarcoma in general.

Keywords: osteosarcoma, metatarsal bones

Accepted 11 x.77

In his book "Fractures and Joint Injuries" Watson-Jones (1960) said, speaking of the metatarsal bones, that "sarcoma of this bone has not yet been reported in thousands of years in any country". He thereby wanted to emphasize how absurd an erroneous diagnosis of sarcoma is when march fractures are so common at this site and to stress the serious consequences that such a mistaken diagnosis may entail and has indeed entailed (Dodd 1933).

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Lee & MacKenzie (1964)	160	2
McEnenna (1966)	253	6
Marcove et al. (1970)	145	1
Jenkin et al. (1972)	62	6
Scranton et al. (1975)	34	6
Price et al. (1975)	125	6
Present material*	49	1
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pendence to Otto Sneppen, Department of Orthopaedic Surgery, Rigshospitalet, DK 2100 Copenhagen Ø Denmark

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— 1982/83

PRACONDYLAR FRACTURE OF THE HUMERUS IN CHILDREN

A Long Term Follow-up Study of 107 Cases

by VÄHVANEN & KARI AALTO

from Children's Hospital, Helsinki, Finland

A total of 107 cases of supracondylar fracture of the humerus in children were examined after a follow-up period of 8 to 11 years. No serious complications were found. Conservative treatment gave good results and open reduction was seldom indicated. Rotational displacement and displacement in the frontal or sagittal plane remodelled by the end of the growth period, whereas tilting of the distal fragment into varus or valgus remained. The position of reduction should be checked roentgenologically until bony consolidation occurs by measuring Baumann's angle or the carrying angle and rereducations should be performed within 2 weeks.

Key words: supracondylar fracture, humerus, children, Dunlop's traction, long term follow up.

Accepted 12 x 77

Supracondylar fracture of the humerus is a common fracture in children. Between 40 and 50 per cent of all fractures in the elbow region are of this type (Blount et al 1951, Blount 1955, El-Sharkawi & Fattah 1965, Eriksson 1966). The treatment of these fractures presents certain difficulties even to experienced surgeons. It is common to classify supracondylar fractures into two main groups according to the direction of the force of the injury: the rare flexion type which constitutes 1 per cent of cases according to Blount (1955) and the more common extension type of fracture. Good results after closed reduction and immobilization of the elbow joint into flexion and pronation have been reported by many authors (Baumann 1929, Sims 1939, Blount et al 1951, Blount 1955, Watson-Jones 1962, Charnley 1963, Sharrard 1971, Izadpanah 1973). Many extension-type fractures may be immobilized in extreme flexion with a collar

and cuff, without the use of plaster (Blount et al 1951, Watson-Jones 1962, Charnley 1963).

El-Sharkawi & Fattah (1965) treated supracondylar fractures with reduction and immobilization of the elbow joint in full extension and supination. Baumann (1929) recommended traction in severely displaced cases, especially if the patients came for treatment late. Skin traction after reduction was introduced by Dunlop (1939). The same method was used later by Allen & Gramse (1945), Mitchell & Adams (1961) and Decker (1972). Hagen (1964) used skin traction over the head. Skeletal olecranon traction was used by Hoyer (1952), Madson (1955), Smith (1960, 1967) and Rozman (1975). The latter method was preferred as treatment of severely displaced fractures by Smith (1971) and Tachdjian (1972). Swenson & Flynn et al (1974) and Fowle & Evans (1974) preferred closed reduction of the fracture with fixation of the forearm in the

percutaneous Kirschner or Steinmann wires

This paper presents an investigation of the treatment of supracondylar fractures of the humerus in children comparing treatment by closed reduction and plaster immobilization with treatment by reduction, traction and plaster immobilization, as regards end results and growth disorders. We also tried to determine the range of displacement which could be accepted primarily if a good end result was to be obtained

PATIENTS AND METHODS

The series consisted of 107 dislocated supracondylar fractures of the humerus in children under 15 years of age, treated as inpatients at Aurora Children's Hospital Helsinki, Finland in the period in 1957-1967. Of the total number of 176 patients, 36 were excluded from our study because there was neither fracture dislocation nor reduction. 107 out of 140 inpatients (76 per cent) were contacted and examined by the authors during 1973-1975. Some of the remaining 33 patients (33/140) were excluded because of the unacceptable quality of the primary radiographs.

The age and sex distribution is shown in Figure 1. The age of the patients varied from 1.5 to 14 years with an average of 7 years. The highest frequency of fractures was found in the age group 3 to 9 years. The ratio between left and right

was 67:40. Fractures were sustained most during the summer and autumn. The cause of the injury is presented in Table 1. There were no open fractures. The fractures were classified into five groups according to the mechanism of the trauma and the degree of dislocation (Figure 2). Flexion type fracture (groups II and III) occurred in 12 cases (11 per cent), and the extension type (groups IV and V) in 87 cases (81 per cent). Eight cases (8 per cent) with only rotational displacement made up group I.

Treatment was closed reduction and plaster immobilization in 35 cases (32 per cent), reduction and Dunlop's skin traction in 58 cases (54 per cent) (Figure 3). Seven cases (7 per cent) were immobilized without reduction and seven cases (7 per cent) were treated surgically (Table 2). In the seven surgically treated cases conservative reduction was tried first without success, but because of loss of the pulse in the radial artery in four cases and failure to maintain an acceptable position of the fracture with closed reduction in three cases, open reduction was performed

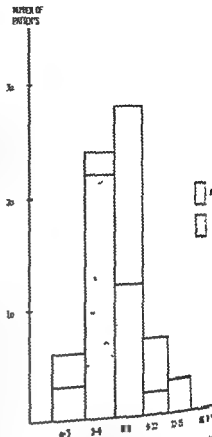


Figure 1 Distribution of the fractures according to age in years at the time of injury

including fixation of the fragments with Kirschner wire or cerclage.

The flexion type fractures were treated with the elbow joint in full extension and traction. Dunlop's skin traction was used in one case. Severe posterior dislocation and in some cases reduction could not be obtained. Rereducations were done in 25 cases. Traction was maintained for 4 to 23 days, after which traction was removed and the arm was immobilized with plaster. The total period of treatment lasted on average 30 days.

Residual deformity was studied radiographically. In order to estimate varus or valgus deformity, the angle between the lateral epicondylar line and

Table 1 Mechanism of the trauma

Fall from a height
Fall on the same level
Sports accident
Compression/twisting

Total

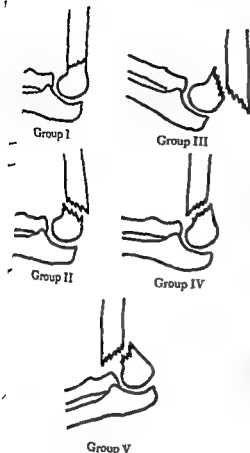


Figure 2 The distribution of the fractures in the different groups of displacement in the sagittal plane (Henrikson 1966, with the author's permission)

Group I
displacement (according to Henrikson) but the cases in our series with only slight rotational displacement are included in this group

Group II
an angle ($< 20^\circ$) dorsally and/or with anterior displacement less than the breadth of the bone. Four patients.

Group III
an angle ($> 20^\circ$) dorsally and/or anterior displacement equal to the breadth of the bone. Eight patients.

Group IV
an angle ($< 20^\circ$) anteriorly and/or dorsal displacement less than the breadth of the bone. Only two patients.

Group V
an angle ($> 20^\circ$) anteriorly and/or dorsal displacement of the distal fragment by more than the breadth of the bone. Sixty-five patients.

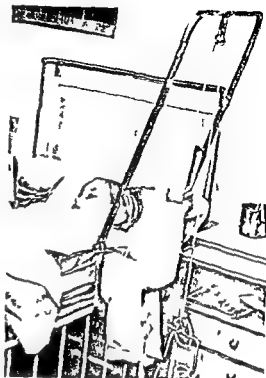


Figure 3 Modified Dunlop's skin traction with posterior plaster splint

longitudinal axis of the humerus was measured according to Baumann (1929) (Figure 4). After the closure of the epiphyseal lines, an analogous comparison of the angle between the trochlear axis and the longitudinal axis of the humerus, the carrying angle (CA) was made. The cubital axis was also measured clinically, and the range of motion and the patients' subjective complaints were registered.

The duration of the follow-up ranged between 8 and 18 years, on average 12 years. The age of the patients at the follow up was 12 to 26 years, average 18 years.

RESULTS

Primary results

The primary roentgenological results evaluated according to the criteria in Table 3 were good in 59 cases (55 per cent), fair in 44 cases (41 per cent) and poor in 4 cases (4 per cent) (Table 4). All of the seven fractures treated surgically healed without any com-

percutaneous Kirschner or Steinmann wires

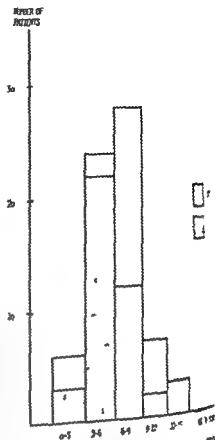
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tomy was performed because of return of peripheral pulse. The recovery was rapid and complete.

Results

Röntgenological results at the follow up evaluated according to the criteria in Table 3, were good in 87 cases (81 per cent), fair in 12 cases (11 per cent) and in 8 cases (8 per cent) (Table 5).

The primary and late results in the groups treated with plaster immobilization and those treated with traction and plaster immobilization are seen in Table 6. The late results do not differ significantly from the primary ones ($2.33 < \chi^2_{0.05} = 3.99$).

Primarily the varus/valgus deformity, i.e. difference in the cubital angle on both sides, related with that of the röntgenological angulation. Restriction of extension by 10° was present in two cases, limitation of flexion by less than 10° in ten cases and between 10 and 20° in another four cases. Rotational movement was normal in all cases.

In the late follow up study seven cases were classified as poor because of varus, and one case because of valgus angulation. The valgus angulation and two cases of varus amounted to 15°. None of these patients required any treatment. In five cases with 25° of varus however a corrective osteotomy was performed.

Comparison of primary and late results

In comparing the results of the primary and late follow up examinations, it is quite clear that rotation and displacement of the distal fragment in the frontal or sagittal plane, resulting in a primary classification of fair or poor, had disappeared at the time of follow-up. The only exceptions were three cases with tilting of the distal fragment in two cases varus of 15°, and one case valgus of 15°. In the evaluation of the eight cases classified as poor at the follow up compared with the four cases with this classification after the primary fracture treatment we could see the following points of interest. Of these

Table 5 Late röntgenological results

Group	I	II	III	IV	V	Total	Per cent
Good	7	4	5	17	54	87	81.3
Fair	1	—	1	2	9	12	11.2
Poor	—	—	2	3	2	8	7.5
Total	8	4	8	22	65	107	100.0

Table 6 Comparison of the primary and late results in cases treated by closed reduction and plaster and reduction combined with skin traction

Method	Primary result			Late result		
	Good	Fair	Poor	Good	Fair	Poor
Reduction and plaster (cases)	20	12	3	27	3	5
Reduction and skin traction (cases)	30	27	1	50	5	3
Total (93 cases)	50	39	4	77	8	8

plications. Volkmann's contracture did not develop in any of the cases. A transient radial nerve injury was present in two patients (2 per cent). In four cases (4 per cent) roentgenological changes of myositis ossificans were seen, which later disappeared completely.

In our series there were vascular complications in four cases (4 per cent). Loss of pulse in the radial artery was found after the fracture reduction and surgery was performed immediately. In each of these four cases the brachial artery was found to be compressed between the fracture fragments. No

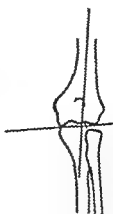


Figure 4A
Carrying angle



Figure 4B
Bony union

Table 2. Methods of treatment

Group	I	II	III	IV	V
Immobilization with plaster splint	5	—	—	2	—
Closed reduction and plaster splint	3	4	4	11	13
Closed reduction and Dunlop traction	—	—	3	9	46
Open reduction osteosynthesis/traction	—	—	1	—	6
Total	8	4	8	22	65

Table 3. Criteria used in the evaluation of roentgenological results

Result	Ad latum*) AP projection	Lateral projection	Ad axum	Tilting	Rotat.
Good	$\leq 1/4$	$\leq 1/4$	$\leq 15^\circ$	$\leq 5^\circ$	$\leq 5^\circ$
Fair	$\leq 1/2$	$\leq 1/2$	$\leq 20^\circ$	$\leq 10^\circ$	$\leq 10^\circ$
Poor	$> 1/2$	$> 1/2$	$> 20^\circ$	$> 10^\circ$	$> 10^\circ$

*) Displacement measured as part of the diameter of the bone

Table 4. Primary roentgenological results

Group	I	II	III	IV	V	Total
Good	7	4	3	15	30	59
Fair	1	—	5	6	32	44
Poor	—	—	—	1	3	4
Total	8	4	8	22	65	107



Fig. 5 (a) Transverse fracture of the left humerus (January 6) in a 77 year-old woman (b c) X rays of patient at follow-up on October 15. Position of fracture had not changed since January 21 when mobility of arm had been so good that the patient was satisfied and declined further treatment.

Transverse fracture of the right humerus and treated with a hand sling but within 2 weeks, against medical advice the patient returned to work where his activities included, among other things, lifting pans to head height. Healing was delayed with the development of pseudarthrosis so that 2 months after the accident the arm was placed in a long-brachial plaster to prevent further use of the arm. The plaster was, however, split to permit free movement of the shoulder and elbow. 2 months later the arm was united.

Stiffness of the arm. In transverse fractures, stiffness was rare if the patient was youthful. A shortening of a few centimetres occurred in two elderly patients who because of other injuries were bedridden; however, the fracture fragments remoulded and the final result was functionally satisfactory.

Some shortening also occurred in association with the healing of oblique or spiral fractures, but again such shortening caused no functional impairment.

Angulation. This complication did not occur to any significant extent in patients with oblique or spiral fractures. Transverse fractures occasionally showed an open angle of 10–15°, usually anteriorly but there was no limitation of function.

Impairment of function of the upper limb joints. A temporary impairment of shoulder movement was noted in elderly patients in whom a fracture line extended towards the neck of the humerus. None of the patients had any impairment of movement in the elbow, wrist or hand.

Refracture. One case occurred. The patient was an 84-year-old man with advanced arthrosis deformans coxae who had an

PROLIFERATION OF BONE MARROW AND THYMUS CELLS AND INCREASED OSTEOCLASIA AFTER ANTIGENIC CHALLENGE IN RATS

ANDERS HULTH & OLOF JOHNNELL

Department of Orthopaedic Surgery, Malmö General Hospital
University of Lund, Malmö, Sweden.

Injection of a single dose of an antigenic substance (sheep red blood corpuscles) in young rats results in a significant rise in the number of cells in bone marrow (and in thymus) and in addition a significant number of osteoclasts in the metaphyses of the ribs. This osteoclastia appears 3 days after the peak values of the bone marrow thymus mitoses. This and earlier investigations make it probable that there is a causal relationship between bone marrow stimulation and osteoclastia.

Key words: bone marrow, thymus, osteoclasts, antigen, mitosis.

Accepted Jan 77

Standardized bleeding, injection of calcium and EDTA, stimulate the rate of mitosis in bone marrow and thymus in rats (Perris & Whitfield 1967a,b, Perris et al 1971). The common factor in this mechanism is a parathyroid-dependent hypercalcemia. The authors of the present paper have shown that fractures of the femur (Hulth & Johnell 1976a), partial aspiration of bone marrow (Hulth & Johnell 1976b) and soft tissue wounds (Johnell 1977), in rats, also result in stimulation of mitosis of intact bone marrow and of thymus. Whether or not this reaction is also governed by PTH is not clear, but hypercalcemia occurs at fractures. In addition, fracture of the femur and bleeding in rats result in proliferation of bone resorbing osteoclasts in rib metaphyses (Johnell & Hulth 1977). Perris & Morgan (1976) have related in a review article an unpublished investigation showing that injection of an antigen, red blood corpuscles of sheep (S-RBC), in rats, also causes an increased mitosis rate 3 days after the injection. The question is does increased mitosis rate in

bone marrow *per se* result in increased osteoclastia. We have therefore studied the effect of antigen injection on the number of osteoclasts in the rib metaphyses.

MATERIAL AND METHODS

Three groups of 40, 42, and 30 rats, respectively, weighing 120-130 g were used, each including a control group of 7 rats. The first two groups were used for osteoclast counting and the third for mitosis counting. All the experiments were given intravenously in a tail vein. The first group, a pilot study, 10 rats, S-RBC in saline = 2.1×10^{10} RBC/ml. The second group, 20 per cent S-RBC = 4.1×10^{10} RBC/ml. The animals were sacrificed 1, 2, 3 and 5 days after injection. The first groups also after 7 days. The rats were in good condition and were not influenced by the antigen.

Osteoclast study

Blood was collected to determine Ca⁺⁺ and hematocrit. In all rats the ribs of the fifth ribs were taken out. The bone

d for approximately 20 hours in a 10 per cent solution of EDTA, containing 0.1 M tris.

The bone was then washed in cold saline, frozen in liquid nitrogen and then cut in a 5-6 sections 10 μ thick being made. Sections were cut at 30 μ intervals in order to visualize the appearance of the same osteoclast in different sections. The sections were stained for acid dehydrogenase activity by the method of Histochemical Society with nitroblue tetrazolium salt as the Histochemical (Tatevossian 1973).

Osteoclast count was carried out as in the rib metaphysis of the rib and

osteoclasts occurring in the marrow cavity were also counted.

Albumin was determined by the cresol green method, serum calcium being analyzed by flame photometry. Hematocrit taken in all animals.

Study

Rats were given two injections of colchicine peritoneally, the first 6 hours (0.2 mg/100 g) and the second 3 hours (0.2 mg/100 g) before the rats were sacrificed by either choice of two injections of colchicine was given to prevent the escape of cells in metaphase. The initial block. All animals were given the injections at the same time the first injection given 8-8.30 a.m., in order to avoid the diurnal fluctuations in mitotic activity of bone marrow and thymus cells (Hunt & Ferris 1974). The thymus gland and femoral bones were removed. Thymocyte and bone marrow cell suspensions were prepared in a balanced glucose medium [5.5 mM glucose, 5.0 mM KCl, 3 mM CaCl_2 , 1.0 mM MgSO_4 , 5.0 mM Na_2O , 120 mM NaCl, 5.0 mM Tris buffer (pH 7.2)]. The thymocyte suspension was prepared by mincing the gland in the medium with scissors, the resulting suspension being filtered through gauze. To prepare the suspension of bone marrow cells, the ends of each femur were removed and the core of marrow was "washed out" with 15 ml of the medium and then dispersed by passing the tissue several times through a syringe with an 18 gauge needle. Then the thymus and bone marrow suspensions were gently centrifuged.

Samples of the cell suspensions were placed on slides and immediately fixed in alcohol and stained with hematoxylin and eosin. The slides were prepared for the percentage of the total cell popula-

tion in metaphase. Each preparation had two slides and on each at least 500 cells were counted (a total of at least 1000 cells were counted). During the counting procedure the slides were labeled in code.

RESULTS

Injection of 20 per cent S-RBC resulted in a significant increase ($P < 0.001$) in the number of osteoclasts on the 3rd day with the level remaining high—until the 5th day after injection (Figure 1). Ca was normal for the first few days but showed a slight, though not definitely significant, increase on the 5th day. Other changes noted were significant increases in albumin⁸ on the 2nd day and in hematocrit on the 3rd day after injection. After injection of the smaller dose, 10 per cent S-RBC, there was also a significant increase ($0.01 > P > 0.001$) in osteoclasts on the 3rd day after injection. In these animals there was no increase in Ca^{45} , which was also true for the hematocrit.

The results of the mitosis counting of bone marrow cells and thymus cells are shown in

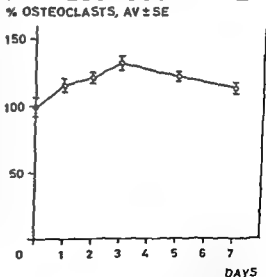


Figure 1 Percentage changes in osteoclast number in rib metaphysis after injection of a single dose of 20 per cent S-RBC. The osteoclast number in the control animals is expressed as 100 per cent.

Figure 2a and b In control animals 6 hours after the first colchicine injection 16.8 per cent of the bone marrow population was arrested in metaphase. Similar figures for the thymocytes arrested in metaphase were 6.7 per cent. The increase in bone marrow cells in metaphase was significant after 1 day and highly significant after 2 days. Thereafter there was a return towards normal on the 5th day.

The increase in mitosis among thymocytes was highly significant on the 1st and 2nd day after injection of antigen. The course after the 2nd day is impossible to determine because the values were too widely spread.

DISCUSSION

In the experiments performed we have shown that injection of an antigenic substance (S-RBC) results in a significant increase in the number of mitoses in bone marrow (and also in thymus). In addition the antigen resulted in a significant rise in the number of osteoclasts in rib metaphyses in rat. We were not able to perform the osteoclast counting

and mitosis counting in the same rat because colchicine is known to decrease the amount of osteoclasts in bone marrow (et al 1973). Our experiments show that the maximal effect on mitosis in bone marrow cells occurs on the 2nd day, whereas the maximal osteoclast effect is on the 3rd day. In experiments with rats performed earlier the maximal mitosis and osteoclasts reached the values after 1 day (Hulth & Johannel & Hulth 1977).

An immune response and its effect in common viz. an increase in mitosis of bone marrow cells. The marrow stimulation after bleeding is to a parathyroid-dependent hypercalcaemia. Hypercalcaemia also occurs after bone marrow stimulation. In the present experiments there was an insignificant increase in serum calcium after antigenic challenge. The insignificant increase in serum calcium after antigenic challenge is another mechanism for osteoclast stimulation producing resorption of bone have been investigated during the last few years. In addition to PTH

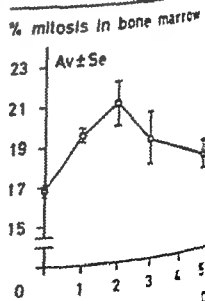
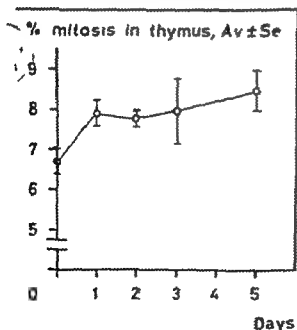


Figure 2a and b Increase in the number of mitoses in thymus (2a) and in bone marrow (2b) after injection of a single dose of 20 per cent S-RBC.

tamin metabolites, osteoclast activating factor (OAF) produced *in vitro* by mitogenic stimulation of lymphocytes (Horton et al 1971), and prostaglandins (Dietrich & Raisz 1975) have also been the subject of study. In connection with immune response, prostaglandins appear to mediate a complement dependent effect of serum on osteoclastic resorption (Dietrich & Raisz 1975). It is probable therefore that the increased osteoclastic resorption in this experiment depends on prostaglandins.

With respect to the substance which mediates the increased osteoclastic activity, it appears to be a mutually dependent relationship between increased mitotic activity of bone marrow cells and increased osteoclastic activity. This provides an interesting insight into the function of bone as an organ in which its two parts are intimately dependent on each other. This aspect, though new, is often overlooked. It is impossible, however, at this stage of the research, to fully evaluate the experimental findings to human diseases, especially to different types of osteoporoses.

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BONE GROWTH ALTERATIONS RESULTING FROM APPLICATION OF CO₂ LASER BEAM TO THE EPIPHYSEAL GROWTH PLATES

An Experimental Study in Rabbits

G MOREIN*, S GASSNER† & I KAPLAN‡

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The CO₂ laser beam was used to create defects 3 mm in depth in the epiphyseal growth plate of one femur in a group of 59 rabbits. In most of the rabbits in which the defect was created on the lateral aspect of the epiphyseal plate the procedure resulted in the subsequent development of valgus deformity and shortening of the femur. In most of the rabbits in which defects were produced both medially and laterally to the epiphyseal plate there was a subsequent marked shortening of the bone. Histologic studies revealed that the laser-induced defects of the growth cartilage resulted in epiphyseal fusion and premature disappearance of the epiphyseal plates.

Key words: carbon dioxide laser, epiphyseal fusion, epiphyseal cartilage

Accepted 2.xii.77

studies performed by Verschuere et al (1975) showed that the use of the carbon dioxide laser beam for osteotomy results in healing without delayed union or pseudoarthrosis, and work done in our Experimental Surgery Unit has shown that bone defects produced by laser beams subsequently fill with new bone. These observations led to the hypothesis that application of the laser beam to the epiphyseal growth plate would produce a defect which would become replaced by bone and would thereby induce an alteration in bone growth. The present study was undertaken to determine the validity of this hypothesis.

MATERIAL AND METHODS

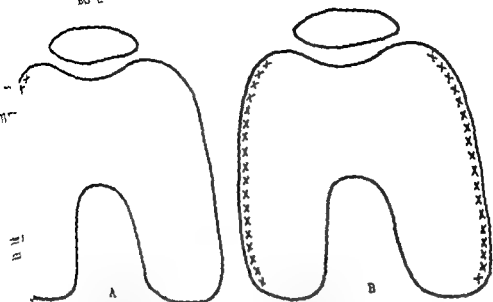
The experimental material of this study comprised a total of 59 rabbits from 3-4 months of age and

weighing 800-900 g. In each animal the distal femoral epiphysis was treated with the CO₂ laser beam, the left side thus serving as a control. The animals were divided into two groups. In the first group (32 animals) an almost semicircular defect 3 mm in depth was produced on the lateral aspect of the epiphyseal growth plate exposed through a small incision in the skin (Figure 1A). In the second group (27 animals) similar defects were produced both on the medial and lateral aspects of the epiphyseal growth plate (Figure 1B). The rabbits were sacrificed from 10 days to 14 weeks after induction of the defect. Both femurs were dissected out, X-rayed and measured. The distal portions of both femurs were fixed and examined microscopically.

Anesthesia during the operation was induced by intravenous administration of Nembutal (pentobarbital) 30 mg per kg body weight.

The "Sharplan 791" CO₂ laser system was used with an output of 7-10 watts.

* Produced by "Laser Interneer Ltd." Israel



1A 1B Schematically-drawn horizontal sections of the distal femoral epiphysis at the level of the plates. The crosses indicate the extent of the defects in each group of animals.

ULTS

roscopic findings

ruptions in the growth of the femurs were found in 54 of the 59 rabbits. Among the 32 which the defect was produced on the lateral aspect of the epiphyseal growth plate showed the development of a valgus deformity which became evident at the end of the third week and was maximal 12 weeks after the procedure.

When compared with the control femurs, the operated femurs were shorter (Figure 2) 16 weeks there being an average shortening of 5.2 mm. In three animals in this group there was no difference between the treated and control sides. Among the 27 rabbits in which the defect had been induced both medially and laterally the most prominent finding was the marked shortening of the femurs in 25 animals, which reached an average of 8.8 mm 16 weeks after the procedure. The metaphyseal region of the operated femurs appeared to be expanded and callus formation on the medial and lateral aspects (Figure 3). In four animals there was a valgus deformity of the distal

femoral epiphysis in addition to the shortening. In two animals in this group there was no difference between the treated and control sides.

Microscopic findings

In both groups of rabbits the defect of the epiphyseal growth plates was found to have been replaced by bone which formed a bridge between the epiphyseal and metaphyseal parts of the femur and which resembled the callus formation seen at fracture sites (Figure 4). Evidence for the formation of these bone bridges was already found in the animals sacrificed as early as 10 days and by 3 weeks they were seen to be fully formed. From 5 to 7 weeks after the procedure the epiphyseal plates were found to be narrowed and the number of cells in the cartilage columns decreased in comparison with the control side. In animals sacrificed 9 weeks or more after the operation there was no epiphyseal cartilage on the operated side (Figure 5A) whereas on the control side it was still present, corresponding with the animal's age (Figure 5B). In some specimens there was a thin cortical plate of bone

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Key words: carbon dioxide laser, epiphysiodesis, epiphyses, growth cartilage.

Accepted 2.xii.77

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MATERIAL AND METHODS

The experimental material of this study comprised a total of 59 rabbits from 3-4 weeks of age and

weighing 800-900 g. In each animal the right distal femoral epiphysis was treated with the laser beam, the left side thus serving as a control. The animals were divided into two groups. In one

both on the medial and lateral side of the epiphyseal growth plate (Figure 1B). The animals were sacrificed from 10 days to 16 weeks after induction of the defect. Both femurs were then dissected out, X-rayed and measured. Sections of the distal portions of both femurs were prepared and examined microscopically.

Anesthesia during the operation was consisted of intravenous administration of Nembutal (pentobarbitone), 30 mg per kg of body weight.

The 'Sharplan 791' CO₂ laser apparatus was used with an output of 7-10 watts.

* Produced by 'Laser Industries Ltd.' Israel

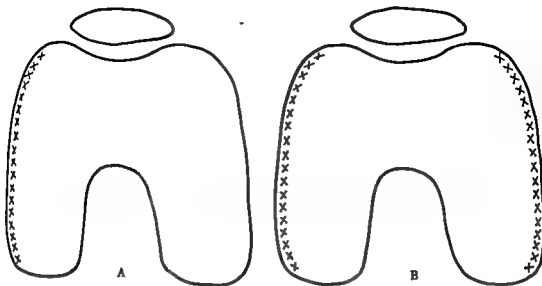


Figure 1A, 1B Schematically drawn horizontal sections of the distal femoral epiphysis at the level of the growth plates. The crosses indicate the extent of the defects in each group of animals.

RESULTS

Macroscopic findings

Alterations in the growth of the femurs were found in 54 of the 59 rabbits. Among the 32 in which the defect was produced on the lateral aspect of the epiphyseal growth plate, 29 showed the development of a valgus deformity which became evident at the end of the third week and was maximal 12 weeks after the procedure.

When compared with the control femurs, the operated femurs were shorter (Figure 2), at 16 weeks there being an average shortening of 5.2 mm. In three animals in this group there was no difference between the treated and control sides. Among the 27 rabbits in which the defect had been induced both medially and laterally, the most prominent finding was the marked shortening of the operated femurs in 25 animals, which reached an average of 8.8 mm 16 weeks after the procedure. The metaphyseal region of the operated femurs appeared to be expanded, with callus formation on the medial and lateral aspects (Figure 3). In four animals there was a valgus deformity of the distal

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Figure 2 Normal control femur (on left) and operated femur (on right) 16 weeks after creation of lateral defect. Operated femur shows shortening and valgus deformity



Figure 3 Normal control femur (on right) and operated femur (on left) 8 weeks after creation of medial and lateral defects. Note shortening of the operated femur and callus formation on medial and lateral aspects of metaphysis

replacing the epiphyseal growth plate. In the four animals that developed valgus deformities after the creation of bilateral defects, bone bridges were found only on the lateral aspect of the plate while none developed on the medial side, which had normal epiphyseal cartilage. In the five animals in which there were no alterations in bone, the defects were all filled by epiphyseal cartilage and there was no difference between the histological appearance of the control and operated femurs.

X-ray findings

Roentgenological examination revealed normal trabecular structure with signs of

callus formation in the treated area of the femurs.

DISCUSSION

The specific properties of the CO₂ laser beam make it a superior instrument with which to achieve a very fine incision (Kaplan & Stone 1976 Kaplan et al. 1973). It has a wave length of 10.6 microns and emits light energy which is totally absorbed by water so that it can vaporize tissue at its focal point, while leaving the adjacent tissue virtually unaffected. The thermal damage produced is minimal and when it is used with a low power output, practically nil. Soft tissue can

be incised with a low power output of less than 10 watts while for hard tissues such as bone power output of at least 30 watts is required. Thus when a low-power laser beam is applied directly to epiphyseal cartilage it damages the cartilage selectively without affecting the adjacent bone.

The experiments carried out by us showed that when part of the epiphyseal plate is destroyed by means of the CO₂ laser the normal adjacent bone acts like that at a fracture site and the defect is therefore filled by newly formed callus which replaces the growth cartilage and leads to cessation of bone growth. Furthermore, a premature disappearance of the treated growth plates and subsequent bone shortening were also observed in most of the experimental animals. In explanation of the latter phenomenon, it may be assumed that the bone bridges which are firm enough so that they will not break, counteract the longitudinal traction forces exerted by cartilage columns, thus causing an opposing pressure on the growth plates. Gebke (1951) and Sijbrandij (1963) showed that pressure applied to the epiphyseal plates leads to an inhibition of growth and disappearance of the growth cartilage, observations which are compatible with the results obtained in our experiments.

In those femurs that remained unaffected by the procedure, the defects were filled by

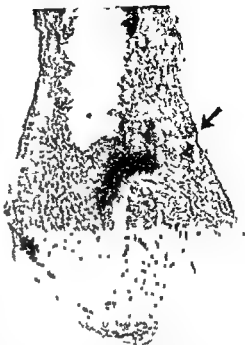


Figure 4 Histological section of distal part of the femur 3 weeks after creation of lateral defect. The arrow indicates the bone bridge between the epiphyseal and metaphyseal parts of the femur

epiphyseal cartilage which apparently served as an interposing material and thus prevented the formation of a bone bridge. Thus regeneration of the growth plates taking place before a bone bridge could be formed while still unexplained, is a phenomenon which has



Figure 5A Histological section showing absence of epiphyseal growth plate 9 weeks after creation of lateral defect

Figure 5B Normal epiphyseal growth plate on opposite femur of the same animal

been observed by a number of authors (Langenskiöld & Edgren 1949, Heikel 1960, Österman 1972, Langenskiöld 1975)

The information provided by this study on rabbits may well prove valuable in the further development of orthopedic procedures designed to correct certain types of deformities as well as inequalities in limb length

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RESECTION AND RECONSTRUCTION FOR BONE TUMOURS

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For the surgical treatment of tumours in long bones a technique in which the resected bone segment is autoclaved and replaced is described.

The results in three patients who had undergone this operation 7 to 11

months after the operation are reported. The results are compared with the results of other techniques. The results of the operation are compared with the results of other techniques. The results of the operation are compared with the results of other techniques.

a similar way are reported from the literature

Key words: autoclaved bone, bone transplant, bone tumours, dia-epiphyseal resection, knee arthrodesis

Accepted 25 x 77

Extensive diaphyso-epiphyseal resection is advisable for bone tumours in long bones when amputation appears to be too drastic and local excision insufficient. This kind of treatment is indicated in the malignant type of giant cell tumours and in chondrosarcomas. Even in special cases of osteogenic sarcoma, local resection seems justified.

Among the many procedures that have been advocated are the insertion of a prosthesis or a massive homograft in an attempt to preserve the mobility of the joint. A hemi or total joint prosthesis is only good therapy for patients with a relatively short life expectancy, it is not an acceptable treatment for those who are in middle age or younger and need a strong leg.

In this paper a description is given of three patients in whom the bone segment containing the tumour was resected. Reconstruction

of the continuity of the bone was achieved by replacement of the bone segment, after autoclaving, and addition of free fresh autogenous bone chips.

OPERATIVE PROCEDURE

A tourniquet is used. The tumour-bearing portion of the femur or tibia is resected to a sufficient distance on either side of the tumour so as to include healthy bone. If there is destruction of the cortex of the bone by the tumour the adjoining soft tissues are taken away. Also the scar of a previous biopsy is excised. Next the resected bone segment is autoclaved at 120°C for 15 minutes. After this treatment the bone segment can be easily freed of soft tissues such as periosteum, parts of joint capsule and tendons and all the bone that is weakened by tumour growth.

The next step in the operation is reconstruction of the continuity of the bone. In order to arthrodesis the knee the joint surfaces are sawn

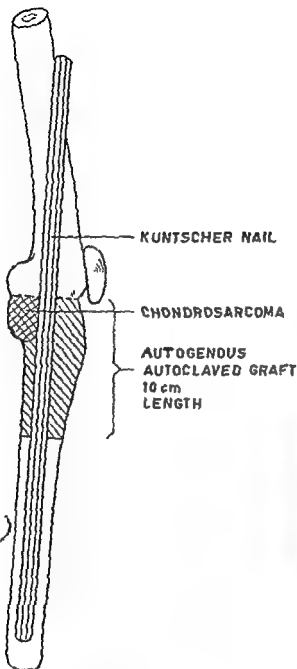


Figure 1 Diagram of the operative procedure

off. Then the autoclaved bone segment is replaced in its original bed and fixed with an extra long Kuntscher nail (Figure 1).

To stimulate union and fill the tumour cavity fresh spongy autogenous bone chips from the patella and the resected joint surfaces are used. For the same reason it is advisable to bridge the autoclaved bone segment by one or two fresh cortical tibial grafts from the opposite leg or spongy bone chips from the ilium.

CASE REPORTS

This operative procedure was performed in two patients.

Case 1

In December 1962 a male aged 26 years was admitted to the hospital complaining of pain in the left knee. Radiological examination showed an osteolytic lesion in the proximal end of the left tibia (Figure 2).

From a biopsy specimen a chondrosarcoma of a low degree of malignancy was diagnosed. The case was sent to the Dutch Bone Tumour Committee. Following the Committee's advice resection of the proximal end of the tibia was carried out. After autoclaving of the resected segment the knee was arthrodesed as is shown in Figure 1. This operation was carried out in February 1963. For the postoperative radiographs see Figure 3. In April 1967 the Kuntscher nail was



Figure 2 Case 1 Chondrosarcoma in the proximal end of the left tibia



Figure 3 Case 1 Radiographs of the left knee 18 months after the operation



Figure 4 Case 1 Radiographs 1-11 years after the operation.

extracted. In the same month spontaneous fracture developed in the area of the autoclaved segment. This fracture was stabilized with a massive cortical autogenous tibial graft and six screws. The radiographs of this case in the period from 1964 till 1974 are shown in Figure 4.

In July 1964, 17 months after re-implantation of the autoclaved segment a specimen from this segment was taken for microscopical examination.



Figure 5 Case 1 Histological pattern of the autoclaved bone 17 months after re-implantation (270x). There is necrotic bone adjacent to highly vascularized fibrous tissue and osteoid tissue.



Figure 6 Case 2 Osteolytic lesion in the lower end of the femur giant cell tumor of the bone.

The pathologist found necrotic bone surrounded by zones of revascularization and an yet immature osteoid tissue (Figure 5).

Case 2

In October 1966 a female aged 33 years came to the hospital complaining of pain in her left knee of 6 months duration. Radiographs showed a radiolucent non trabeculated area, 4 cm in diameter, in the lower end of the left femur (Figure 6). From a microscopic examination it was



Figure 7 Case 2 Radiograph of the left knee 6 months after the operation.

cortical autograft. The method provides a stable extremity in the uncomplicated cases within approximately 1 year.

Several authors have reported transplantation of dead bone (boiled bone, os purum, decalcified bone, ashed bone and frozen bone) both in experimental and clinical research (Lloyd Roberts 1952, Ehlert 1953, Chase & Herndon 1955, Williams 1964, Wilson & Lance 1965 and Parrish 1966).

It is generally accepted that fresh autogenous bone grafts fuse more quickly than all other kinds of bone transplants. To prevent non-union it is wise to bridge a massive autoclaved bone graft with fresh autogenous grafts to initiate rapid partial fusion. Nevertheless it is necessary to establish a rigid internal fixation with long-term stability. This can be realized with a long intramedullary nail and if necessary additional screws to neutralize torsional forces. It guarantees the stability of the bone structures till solid fusion has occurred. Boiled autografts are with regard to acceptance by the host and the period required for fusion in our opinion, comparable with grafts from the bone bank (frozen homografts). The advantages of boiled autografts are:

- (a) The immediate availability, which is of special importance if there is no bank bone obtainable.
- (b) The excellent fit of the graft which facilitates the operative procedure.
- (c) Extensive use of bone from donor sites is not required.

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V-Y PLASTY AS TREATMENT OF FINGER TIP AMPUTATIONS

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V-Y plasty was performed in 28 patients who suffered from a transverse amputation of the finger tip. Bilateral V-Y plasty was carried out in 16 cases and single volar V-Y plasty in 12 cases. The average follow-up period was 32 months. Six patients had postoperative complications, requiring reoperation in four patients. The follow up results were satisfactory. The results showed that V-Y plasty is indicated in transverse amputations through the distal one-third to one-half of the nailbed but only in patients to whom the length of the finger is of importance.

Key words: amputation, finger-tip, V-Y plasty

Accepted 24.1.78

Amputation of the finger tip is a minor injury, but it is important because of an often proportionately long period of convalescence. Moreover, there is usually a high frequency of late sequelae such as a feeling of coldness, diminished or absent sensation, tenderness, deformed nail and joint stiffness. In traumatic finger tip amputations the demands of a satisfactory treatment are:

- The sensibility must be as normal as possible
- The stump must be non-tender
- The nail must not be an inconvenience
- The length of the finger should be maintained if possible
- The movements of the joints must be free
- The cosmetic result should be satisfactory

If the bone is exposed by a transverse amputation of the finger tip, all these demands can best be met by a V-Y plasty. Whether bilateral or single volar. Late results of V-Y plasties have hardly ever been elucidated and therefore we think that our results might be of interest.

METHOD

Digital nerve block anaesthesia is used and a small Penrose drain is applied at the base of the finger as a tourniquet. All devitalized tissue is excised and the bone is smoothed.

Bilateral V-Y plasty (Kutler 1947) Two triangular flaps are developed by cutting only

(without damaging the neurovascular supply) the two flaps can be mobilized to cover the tip of the finger. The flaps are sutured together and to the remaining nail or nailbed (Figure 1B). Prior to closing the volar portion of the skin it is often necessary to remove some excess pulp.

Volar V-Y plasty (Atasoy et al 1970) A triangular flap with a distal base is developed (Figure 2A). The width of the base should be the

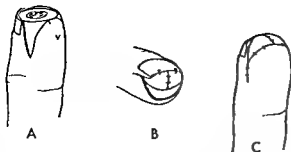


Figure 1 The operative procedure in a bilateral V-Y plasty (see text for details)

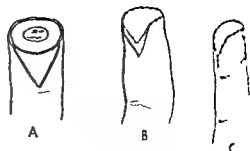


Figure 2 The operative procedure in a tenodesis V-Y plasty (see text for details)

A petrolatum mesh and sterile gauze are applied to cover the stump. The finger is immobilized in a plaster of Paris cast and the hand is kept in a sling for a week.

PATIENTS

From January 1972 to December 1976 28 patients were treated with a V-Y plasty after having sustained a transverse finger tip amputation with the bone exposed. There were 24 men, one woman and three children. The average age was 34 years, ranging from 2 years to 63 years. The amputations were in 16 cases caused by a sharp cutting instrument (planing machines, cutting machines, knives) and in 12 cases by a blunt injury (doors, chains, seesaws, circular saws). All except the children were treated as out-patients in digital nerve block anaesthesia. The operations were carried out by surgical house officers without special experience in hand surgery. The choice between the two types of V-Y plasty has rested on the discretion of the surgeon. Bilateral V-Y plasty was performed in 16 cases and volar V-Y plasty in 12 cases. All the patients had injured only a single finger. V-Y plasty was performed most often on the index (13 cases) and middle (9 cases) finger.

At the follow-up one patient had died and two patients refused to participate. One patient later had an exarticulation at the distal interphalangeal joint due to hypersensitivity of the stump and therefore has been excluded from the late results. The evaluation has been made from case records and a personal follow-up examination. The average follow-up period was 32 months, ranging from 6 months to 57 months. The time interval until healing and the postoperative complications were based on the case records. At the follow-up the patients were asked about the period of time off work and their subjective late sequelae. Tenderness was evaluated by palpation of the stump and by tapping the stump firmly on a table. Light touch was tested using cotton-wool.

RESULTS

Postoperative complications were seen in six patients. Five of these had infection, in four cases due to a total or partial flap necrosis. In one of these a small re-amputation was performed. After healing was established another patient was re-operated due to a very localized tenderness between the two flaps and the nail and one patient had as mentioned an exarticulation in the distal interphalangeal joint due to hypersensitivity of the stump.

The time interval until healing occurred and the period of time off work are listed in Table 1. There was no difference between the two groups regarding age and occupation.

None of the stumps were tender to pressure but firm tapping of the stump against a table showed tenderness in 58 per cent (Table 2). Light touch was present in all patients, but 71 per cent indicated that the feel of cotton wool was slightly abnormal compared with this sensation on other fingers (Table 3). In seven patients (32 per cent) the nail was curved, and a straight normal nail was only seen in amputations through the distal third of the nailbed. All patients had free movements of the joints.

DISCUSSION

When an evaluation of the late results of finger tip injuries is to be made one would like to base the conclusions on at least

findings. However, no objective measurements or tests are available for testing the small dermal areas in a V-Y plasty.

Using the two-point discrimination test abnormal values are often set at around

6 mm, but this is the same size as one side of the small triangular flaps in a bilateral V-Y plasty. Therefore, a two-point discrimination test would be meaningless in as much as it is often difficult to determine the borders of the flaps.

The ninhydrin test demonstrates the sudomotor function. The tactile gnosis varies directly with the sudomotor function except in skin grafts, which regain sudomotor function after a year or so (Moberg 1958). For this reason the ninhydrin test cannot be used for an objective evaluation of the late results.

As advocated by Moberg (1958) the picking up test should be a fairly good test when applied to the thumb and the index finger and maybe the middle finger. At the follow up examination this test was performed by all the patients (both with eyes open and blindfolded). The results have not

Table 1 Duration of treatment in 25 patients

Type of V Y plasty	Average period until healing	Average period off work
Bilateral	21 days (10-60)	61 days (14-180)
Volar	21 days (9-40)	50 days (14-47)
Total	21 days (9-60)	51 days (14-180)

Children and students omitted (no manual work)

Table 2 Subjective late sequelae at follow-up of 24 patients treated with V Y plasty

Type of V Y plasty	Coldness	Tenderness on percussion	Difficulty in grasping small objects	Paraesthesia	Total
Bilateral	8 57%	10 71%	6 43%	0 —	14
Volar	4 40%	4 40%	5 50%	1 10%	10
Total	12 50%	14 58%	11 46%	1 4%	24

Table 3 Objective late sequelae at follow-up of 24 patients treated with V Y plasty

Type of V Y plasty	Light touch missing	Slight hypaesthesia or dysaesthesia	Unable to differentiate pin prick and blunt	Curving of the nail	Total
Bilateral	0 —	10 71%	0 —	4 31%	14
Volar	0 —	7 70%	0 —	3 33%	10
	0 —	17 71%	0 —	7 32%	24

been listed in Table 3 as the patients often did not use the flap itself but an area immediately adjoining the flap.

For these reasons one is left with a mainly subjective basis upon which the evaluation of the late results has to rest.

In finger tip amputations the methods of repair include (1) conservative treatment (2) free skin grafting (3) re-amputation, (4) local flaps and (5) pedicle flaps.

Conservative treatment should be the method of choice in finger tip amputations without exposed bone. Boysen-Møller et al (1961) found that conservative treatment gave a sensibility closer to normal and a better cosmetic result than free grafts. This was confirmed by Holm & Zachariae (1974) who furthermore found a higher frequency of skin trouble and abnormal mobility in those receiving free grafts compared to the conservatively treated group. In both series the period off work was a little longer in patients receiving free grafts than in those treated conservatively.

Free skin grafting should accordingly only have a minor place in the treatment of finger tip amputations. Rohleder (1960) compared the late results of split skin grafts to full thickness grafts. He found no difference regarding sensibility and tenderness but the donor site on the forearm was very conspicuous in 50 per cent of cases after full-thickness grafting and only in 11 per cent after split-skin grafting.

Re-amputation with removal of sufficient bone to permit soft tissue and skin closure of the stump is probably the most frequently performed operation in finger tip amputations. It should be used when an oblique stump has a ventral or lateral flap to be swung around the stump to the opposite side (Kleinert 1959). The resulting finger tip should thus have good padding and good sensibility. However the stump is often annoyingly tender. After re-amputation with primary closure Boysen-Møller et al (1961), Sturman & Duran (1963) and Holm & Zachariae (1974) found subjective tenderness of the stump in 36 per cent, 51 per cent and

42 per cent respectively. Dorsal sensation of touch was found in 17, 24 per cent of the cases.

Local flaps A bilateral V-Y plasty can be used in a transverse amputation of the finger tip and a volar V-Y plasty both in a transverse and an oblique dorsal amputation of the finger tip. V-Y plasties have been described by Kutler (1947), Fisher (1957), Atasoy et al (1970), Freiberg & Manktelow (1972) and Weston & Wallace (1972) however, the results of a late follow-up have only been reported by Freiberg & Manktelow who examined 10 patients in a series of 5 bilateral V-Y plasties. They found 12th touch to be present in all 10 patients and that 41 per cent (5/8) used the injured finger in precise tasks.

Atasoy et al (1970) reported superficial necrosis in 4 per cent (2/36) of volar V-Y plasties, and Freiberg & Manktelow (1972) found postoperative complications such as flap necrosis and/or infection in 18 per cent (4/22) of bilateral V-Y plasties. In the present series there was no difference regarding postoperative complications and late results between the two types of V-Y plasties except that the average time off work was 8.7 weeks after a bilateral V-Y plasty compared with 4.1 weeks after a volar V-Y plasty (Table 1). The period of convalescence has not been registered in series of V-Y plasties reported earlier. Barclay (1956) found that the average period off work was 9 weeks following a free graft and 11.5 weeks following re-amputation. The same intervals were found by Barth et al. (1960) to be 5.1 weeks and 6.4 weeks respectively.

The outcome of the nail is determined by the level of the amputation. A normal nail can only be expected if the amputation is through the distal third of the nailbed.

Pedicle flaps, i.e., thenar flaps and cross finger flaps are only indicated in very distal finger amputations of the finger tip and in volar amputations of the finger tip with exposed bone. A free graft will either not take or give a poor result and a re-amputation is

mean too much of the finger length will have to be sacrificed. However, pedicle flaps require a surgical expertise which only rarely will be available.

Neither thenar flaps nor cross finger flaps are followed by an acceptable degree of sensibility just as there often remains permanent residual joint stiffness (Brody et al. 1960, Müller 1974). Moreover the donor area often heals unsatisfactorily as reported by Müller (1974) who found that the donor site in the palm was either keloid and puckered or rough and prominent in 63 per cent of cases.

The result of the present study shows that a V-Y plasty is indicated in transverse amputations through the distal one-third to one-half of the nailbed when preserving the maximum length of the finger is important to the patient. However, the post-operative complications show that it is not an operation to be undertaken by beginners.

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EARLY COMPLICATIONS OF PRIMARY SHOULDER DISLOCATIONS

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A prospective study of the complications of primary shoulder dislocation was carried out for the 3-year period 1973-1976

The clinical examination was made initially in the Casualty Department and the patient was re-examined in the Department of Physical Medicine. In the evaluation special attention was given to the condition of the rotator cuff, the blood vessels and the motor and sensory function of the affected extremity.

Sixty three out of 238 patients (26 per cent) presented with the following complications: 29 lesions of the brachial plexus, 21 of the axillary nerve and 28 ruptures of the rotator cuff tendon. Complications occurred more frequently in the age group over 50 years ($P < 0.001$) and in male labourers compared with office workers ($P < 0.05$). If the humerus remained unreduced for more than 12 hours, the frequency of complications increased ($P < 0.01$).

Key words: humerus, shoulder dislocation, tendon injuries, nerve injury.

Accepted 19 XII 77

The humeroscapular joint is the joint which most often dislocates. Although the dislocation is common, little is known of the rate of complications. Whenever there are difficulties with mobilization of the shoulder joint after the primary immobilization, one or other complication is usually responsible.

Reeves (1969) verified by arthrography 27 capsular ruptures in 47 shoulder dislocations. Most of the patients with ruptures were over 50 years of age. Ludin et al. (1975) arthrographed 12 dislocations with peripheral nerve lesions, verifying four incomplete and four complete ruptures of the rotator cuff tendon. London (1971) established the difficulty involved in making an early clinical diagnosis of rotator cuff rupture before the patient is able to move the shoulder. He estimated the frequency of axillary nerve lesions after dislocation to be

10 per cent. Assmus & Meinel (1974) recorded 27 axillary nerve lesions after 10 dislocations and 17 other injuries of the shoulder girdle. In three of the patients the paralysis was persistent. Bourens (1974), Ghutesco et al. (1975) and Malinski et al. (1975) separately reported one lesion of the axillary artery in connection with reduction of a shoulder dislocation. Hoffmeier (1973) reported three lesions of the axillary artery, one of which was a complication of humerus dislocation.

The purpose of this study was to analyse the early complications of primary humeral dislocation.

PATIENTS AND METHODS

This study consisted of 238 primary humeral dislocations treated during the period 1973-1976.

31.12.1976 in the Casualty Department, Clinic of Orthopaedics and Traumatology, University Central Hospital, Helsinki, Finland. The study consisted of 133 men and 105 women.

Before reduction a routine neurological examination was performed and the radial artery of the affected extremity palpated. Often the luxation was radiologically verified.

When the diagnosis was made 5 mg of diazepam was injected intramuscularly. Usually the patient was placed prone on a couch with the affected extremity hanging free over the side of the couch. The position of the shoulder joint was adjusted with the help of cushions until a painless hanging position of the extremity was found. After about 10 minutes the relaxation of muscles around the shoulder joint was checked by the surgeon and by using painless rotatory movement with the hanging humerus the reduction of the shoulder joint was completed. Sometimes an additional intravenous injection of 5-10 mg of diazepam was needed and in this way 88.5 per cent of the dislocations were reduced without general anaesthesia.

After reduction the shoulder joint was examined radiologically (Patients with fractures visible on routine X-ray projections were not included in this study). The patient was then transferred to the Physical Medicine Department where the status of the shoulder joint and the neurological signs of the affected extremity were checked by the same person. After 3 weeks the shoulder joint was examined for ruptures of the rotator cuff tendon according to a scheme published in a previous study (Psaala 1963). Furthermore the deep brachial veins were palpated to exclude deep venous thrombosis.

Strength measurements were used to diagnose nerve and tendon lesions of the affected shoulder using the unaffected shoulder for comparison. Arthrography was seldom necessary. When a

severely degenerated rotator cuff tendon (with connection between joint cavity and subacromial bursa) did not give rise to the clinical picture of rotator cuff rupture, the rupture diagnosis was omitted.

The results were analysed and tested by *t*- and chi-square tests.

RESULTS

Sixty-three out of 238 patients (26 per cent) had some kind of complication (34 men and 29 women) (Table 1). The complications were divided into nerve lesions and rotator cuff ruptures.

The neurological complications consisted of brachial plexus and axillary nerve lesions but no lesions of the suprascapular or long thoracic nerves were observed. Most complications occurred in patients over 50 years of age ($P < 0.001$). Rotator cuff ruptures were only found in patients over 50 (Table 2).

The dislocation was most common in manual labourers, the difference between manual labourers and office workers as regards complications was almost significant ($P < 0.05$). Pensioners had the highest rate of complications (Table 3).

The trauma mechanism was known in 149 dislocations, uncertain in 86 dislocations and not known in three cases. It was possible however, to partially reconstruct the mechanism of trauma in the 86 uncertain cases. Patients who had fallen from a height

Table 1 Complications in the different age groups

Age (years)	Complications		
	Female	Male	
	Complication/Dislocation (%)		
11-20	0	2	11
21-30	2	3	11
31-40	0	2	6
41-50	0	2	13
51-60	6	8	30
61-70	12	16	50
71-80	8	1	43
81-90	1	0	25
Total	29	34	26

Table 2 Types of complications in the different age groups

Age (years)	Plexus lesion	Axillary nerve lesion	Rotator cuff rupture	Number of patients
11-20	0	2	0	2
21-30	3	2	0	5
31-40	2	0	0	2
41-50	1	2	0	2
51-60	8	5	5	14
61-70	14	4	17	28
71-80	1	5	6	9
81-90	0	1	0	1
Total	29	21	28	63

Table 3 Complications in the various social groups

Social group	Complications	Dislocations	Complication/Dislocation (%)
Student	2	14	14
Manual labourer	24	101	24
Office worker	4	48	8
Pensioner	33	74	45
Total	63	237	26

Table 4 Effect of the mechanism of trauma on the complications

Trauma mechanism	Complications	Dislocations	Complication/Dislocation (%)
1 m a height	22	96	23
	7	16	44
	10	37	27
Total	39	149	26

Table 5 Effect of the "nonreduced period" on complications

"Nonreduced period" (hours)	Complications			Complication/Dislocation (%)
	Nerve lesion	Rotator cuff rupture	Total	
< 1	16	10	24	27
1-3	16	5	15	17
3-6	6	7	10	33
6-12	3	0	3	23
12-24	4	5	7	50
> 24	5	1	4	80
Total	50	28	61	26

had the highest rate of complications (Table 4).

More than half of the dislocations were reduced within 3 hours of the accident. The rate of complications increased ($P < 0.01$) if the shoulder was unreduced for longer than 12 hours (Table 5).

No deep venous thromboses in the axillary region were found. The reduction of the shoulder joint did not seem to cause additional complications.

DISCUSSION

In arthritic shoulders in patients over 50 years of age it is possible with or without arthrography to find clinically symptomless capsular ruptures (Pettersson 1942, Olsson 1953). This could be the explanation for the high frequency of capsular ruptures in Reeves' report (Reeves 1969).

London (1971) estimated the frequency of axillary nerve lesions in shoulder dislocations to be 10 per cent, corresponding to the findings in the present study. Bouretz (1974), Ghutesco et al. (1975) and Malinski et al. (1975) each found one case of axillary artery rupture after reduction of shoulder dislocation but this lesion did not exist in this study.

On the other hand four similar combined lesions (rotator cuff rupture and axillary nerve lesion) reported by Ludin et al. (1975) were observed in this study. Furthermore two uncommon combinations were observed: there were five simultaneous rotator cuff and brachial plexus lesions and six axillary nerve and brachial plexus lesions.

Reports of the occurrence of complications in the various social groups seem to be uncommon, neither were there any recent studies of the effect of the length of the

'nonreduced period' on the occurrence of complications.

Complications should be suspected in older manual labourers and when the joint has been dislocated for more than 12 hours.

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PROGRESSION OF A STRUCTURAL SCOLIOSIS DURING TREATMENT WITH GROWTH HORMONE

A Case Report

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A diagnosis of panhypopituitarism was made in an infantile male at the age of 22. Skeletal age was estimated to be 14 years. Thyroxine, corticosteroid and later testosterone was administered. Growth hormone was given initially over a period of ten weeks and later for two and a half years. The

than growth rate *per se*

Key words: growth, growth hormone, panhypopituitarism, scoliosis

Accepted 22.xii.77

A connection between the velocity of growth and the progression of structural scoliosis was demonstrated already in the beginning of the 19th century (Bamfield 1824). The risk of an increase of the spinal deformity is particularly high during periods of rapid growth, for instance, during the prepubertal growth spurt at the age of 11 to 13 years in girls and 13 to 15 years in boys.

This case report illustrates the connection between progression of a thoracic scoliosis and two periods of growth hormone treatment in a man with panhypopituitarism.

moderate hypertension and albuminuria during pregnancy. At parturition he was born in breech presentation. Immediately after delivery he was noted to have muscular cramps in the right arm and the right side of the face. He also developed a hematoma of the right sternocleidomastoid muscle and eventually torticollis.

In 1957 he was admitted to a pediatric department and a diagnosis of pituitary nanism was made. In 1968 he was referred to an endocrine department. At admission he had a height of 143 cm and a span of 146 cm. He weighed 31.5 kg. He appeared infantile and there were no secondary sex characteristics. The thyroid was not palpable and blood pressure was 105/80 mm Hg. He had a slight anemia, but normal serum electrolytes and normal liver and kidney function.

CASE REPORT

The patient is a male born in 1946. The family history is non-contributory. His mother had

Financial support was obtained from the Swedish Medical Research Council, Project no B76-17X-04780-01.

Thyroid function: PBI was 4.1 µg/100 ml and T₄ resin uptake 91 per cent, serum cholesterol 273 mg/100 ml. Iodine uptake increased from 26 per cent to 56 per cent after administration of thyrotropin. On scanning the thyroid gland appeared small but otherwise normal. A provisional diagnosis of secondary hypothyroidism was made and thyroxine administration was started with a

dosage of 0.1 mg daily which was gradually increased to 0.2 mg daily. This dosage was maintained throughout the reported studies.

Adrenal function. Urinary steroids and plasma cortisol were subnormal under basal conditions, but increased following ACTH. No increase was demonstrable following metyrapone. Following the demonstration of ACTH deficiency the patient was put on cortisone acetate perorally 5 mg twice daily. This dosage was increased to 5 mg three times daily in November of 1970.

Gonadal function. Urinary gonadotrophins and later plasma FSH and LH determined radio-immunologically were low. During the time of observation there were no spontaneous signs of puberty and in November of 1970 treatment with testosterone was started.

Growth hormone. Growth hormone levels were low or undetectable and did not increase in connection with insulin induced adequate hypoglycemia. Growth hormone (Kabi 1620 DqP7) was administered 2 mg daily for 1 week. Under metabolic ward conditions this caused a decrease of urinary nitrogen excretion from an average of 9 to an average of 4 mg daily. Thereafter the same preparation was given by injections of 2 mg twice a week from September 28 to December 3 of 1968 (10 weeks).

Growth hormone therapy was resumed with the same preparation (Kabi 1620 DqP7) in February of 1970 that is after 14 months, in a dosage of 37 mg twice weekly and thereafter growth hormone was given continuously until September of 1972 (31 months). The dosage was increased to three injections weekly in April of 1971.

CLINICAL COURSE

On admission at the age of 22 this man was severely retarded physically. The skeletal age was estimated as 14 years. Standing height was 143 cm (compared with the average height of Swedish adult males of 179 cm). A structural scoliosis of 15° according to Cobb (1948) was known to have remained constant for more than 3 years.

Growth hormone therapy induced rapid growth. Simultaneously, the structural scoliosis progressed from 15° to 27° over a period of 10 weeks. Because of this progres-

sion of the scoliosis, growth hormone therapy was stopped. After cessation of growth hormone therapy, growth continued at a slower rate. During this period of 13 months the scoliosis remained stationary.

A Milwaukee brace was constructed and fitted, whereafter growth hormone therapy was resumed when the patient had been adequately braced. In spite of an accelerated growth rate no change in the spinal curve could be demonstrated for 18 months, that is as long as the patient wore the brace all day and all night as recommended. During the following 17 months, growth hormone therapy was continued, but the bracing was inadequate. During this period the scoliosis progressed from 26° to 56°. Growth hormone therapy was again stopped and longitudinal growth ceased, whereas there was a slight additional progression of the scoliosis to 62°.

The total increase in standing height from 143 to 158 cm should be corrected for the spinal deformity which at the time of epiphyseal closure amounted to another 4 cm according to Lind & Bjure (1975).

DISCUSSION

The connection between progression of a thoracic scoliosis and two periods of increased growth velocity induced by treatment with growth hormone has been illustrated. During the second period of treatment a Milwaukee brace, worn as recommended, seemed to be able to prevent the progression of the scoliosis. However, when the patient stopped wearing the Milwaukee brace as recommended the scoliosis progressed rapidly during continued growth hormone therapy. To our knowledge there is no evidence that the stopping of bracing *per se* is followed by a progression of scoliosis and consequently we have interpreted the noted progression as a result of continued growth induced by growth hormone.

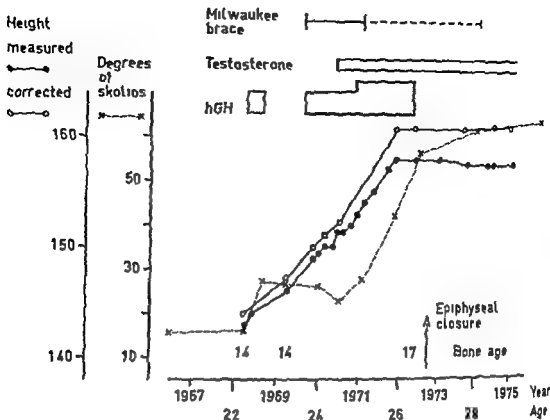


Figure 1 Longitudinal growth and progression of scoliosis in relation to therapy in a male with pan-hypopituitarism

Cortisone and thyroxine were given and there is no indication that either of these substances influenced the clinical course. Testosterone was given only during the latter part of the study, which partly coincided with the most important progression of the scoliosis. There is, however, no evidence that testosterone influences the course of a scoliosis unfavorably. Consequently the inadequate bracing during growth induced by the growth hormone seems to be a more probable explanation for the demonstrated progression.

It is difficult to evaluate whether the progression of thoracic scoliosis was caused by the increased growth velocity as such, or by growth hormone and/or associated substances. An increased serum concentration of growth hormone as well as somatomedin A

has previously been demonstrated in scoliotic girls (Willner et al 1976). Girls with adolescent idiopathic scoliosis also have a different growth pattern compared with non-scoliotic healthy controls. The scoliotic girls have been found to be taller and slimmer at the time of diagnosis and they have grown more rapidly during the year before the diagnosis was made, compared with age-matched controls (Willner 1972, 1974). Skeletal maturation progressed at a slower rate in the scoliotic groups between the age of 13 and 18 years (Nordwall & Willner 1975).

In this patient the scoliosis was stationary for 3 years prior to treatment with growth hormone and for almost one and a half years between the two periods of growth hormone administration. During both these periods growth occurred but at a slower rate. Both



Figure 2 Progression of scoliosis determined on roentgenograms according to Cobb (1948)

these facts seem to imply that either growth hormone or an associated substance is the causative agent, rather than growth *per se*

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1. ANTERIOR INTERBODY LUMBAR SPINE FUSION FOR INCAPACITATING DISC DEGENERATION AND 2. SPONDYLOLISTHESIS

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Anterior interbody lumbar spine fusion by the extraperitoneal technique was performed on 98 patients with incapacitating low back pain due to degeneration of the fourth or fifth lumbar disc (56 patients) or spondylolisthesis (42 patients). Of the discs investigated 135 proved to be degenerated, often severely, and 114 were fused. In 75 per cent of the cases no complications occurred, however, 11 patients developed thrombophlebitis, two fatal pulmonary embolism, four mild pulmonary infarcts, and three pulmonary atelectasis.

At follow-up, 3-8 years later, the fusions were solid in 91 per cent and after re-operation in 94 per cent. Among the patients with spondylolisthesis the fusions were not solid in 14 per cent and among those with disc degeneration in 6 per cent. Improvement or cure was reported by 73 per cent of the patients. Thirty-one patients had constant pain. In 21 of them there was a somatic and in a few also a psychological explanation. Sixty-eight per cent were working. Sixty per cent of those patients who underwent the operation after the age of 45 were receiving a disablement pension.

An attitude of reserve should be taken in operating on patients with a history of one or more operations for disc herniation, as there may be nerve root adhesions. Patients with spondylolisthesis should be followed up for at least 3 years, and if there is a suspicion of incipient pseudarthrosis they should be treated by fusion with screws through the arch defects or by classical posterior spondylodesis. The decision regarding indications for the operation and the operation itself should still be in the hands of very experienced orthopaedic surgeons, and it must be emphasized that the postoperative management, especially the prophylaxis against thrombosis, makes great demands on the staff.

Key words: low-back pain, low lumbar disc degeneration, spondylolisthesis, lumbar interbody fusion.

Accepted 20.XII.77

Anterior interbody lumbar fusion is very seldom used in Scandinavia for the treatment of disc degeneration or spondylolisthesis, and no results of this procedure have been published in the Scandinavian medical literature. Reports in the Anglo-American literature too are scarce considering the

enormous number of patients having incapacitating backache. The results reported have varied within wide limits, presumably because the indications have differed. Some surgeons have abandoned the method because of technical difficulties and complications, or the occurrence of pseudarthrosis.

This study has been carried out with the aim of answering the question of whether the method is worthwhile

PATIENTS AND METHODS

During the period December 1967–May 1973 we performed anterior lumbar interbody spine fusion on 98 patients (pts)

The operative indication was disabling low-back pain due to spondylolisthesis or low lumbar disc degeneration affecting one or at most two discs, the others being normal. For technical reasons, the patients' body weight had to be within the normal range. Ideally, the upper age limit should be 55 years, and the patients should be sufficiently motivated, willing to work, and mentally robust.

Figure 1 gives the sex ratio and age distribution. The age range was 15–58, and most patients were 40–50 years of age. This applies especially to the women who made up 62 per cent of the total.

From Table 1 it is apparent that three-quarters of the patients had suffered from pain for at least 5 years, and one-third had had constant pain for

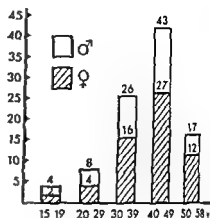


Figure 1 Age distribution and sex ratio

at least 5 years. In 73 per cent the pain radiated to the lower limbs. Nine had previously undergone operation and 11 had been treated conservatively for lumbar disc herniation. During two of 10 fusion operations we removed myelographical confirmed herniations from the front, as there had been little suspicion of free herniations.

Forty-four pts were totally and 35 partially incapacitated. In 19 the working capacity was not affected. Most of the latter were younger persons.

Table 1 Duration of pain

Length of history (years)	No. of patients	No. of patients with constant pain
Less than 1	2	25
1-4	23	41
5-9	17	13
10-14	21	12
More than 15	35	7

Table 2 Lumbar discs affected and the severity of the disc changes

Disc	37 men	61 women	Total 98 pts	135 discs
LD 3	2	1	3	3
LD 4	5	4	9	9
LD 5	17	36	53	53
LD 4 + 5	15	20	35	70
Not narrowed	3	3	6	
Slightly narrowed	14	12	26	
Moderately narrowed	20	19	39	
Severely narrowed	17	47	64	

with symptoms of spondylolisthesis, and the operation was done in an endeavour to comply with their occupational wishes. Prior to the operation nine were receiving disablement pension and eight had changed to another job. Twenty-nine were doing heavy physical work, 67 light work, and seven non physical work.

Radiography showed that in the 98 patients 135 discs were affected (Table 2), usually the fourth or fifth, in 35 cases both. The third lumbar disc was affected in only three pts. Severe narrowing of the disc was present in half the men and two-thirds of the women. Sclerosing of the end plates and marginal exostoses were common findings. Among the females severe lumbo-sacral spondylosis and disc narrowing were the most common operative findings (Figure 2). Second table

10-15 per cent in three (Meyerding 1956). Furthermore the vertebral body was displaced forward in relation to the overlying body in 12 of the 25 males and in 5 of the 17 females. This displacement averaged 6 mm (3-11) but fusion of the overlying disc was done in only two of the 16 pts. In all, fusion was performed on 114 discs.

Surgical technique The patient is placed supine, with the site of fusion on a level with the peak of the kidney hump of the operating table. A paramedian longitudinal incision is made over the middle



Figure 2 X ray showing severe narrowing of the L4-L5 lumbar disc with exostoses and sclerosing of the end plates in a woman of 50

Table 3 Spondylolisthesis site, sex ratio, and grade

Grade of spondylolisthesis	I	II	III
25 men	18	6	1
17 women	8	7	2
Total 42	26	13	3
LD 3	—	1	—
LD 4	—	—	—
LD 5	20	12	3

dian longitudinal incision is made over the middle of the left rectus sheath which is opened. The rectus is loosened and pulled laterally to spare vessels and nerves. The peritoneal sac with extraperitoneal fat, containing the ureter, is gently mobilized from the inferior aspect and pushed upwards to the right, and the iliac vessels are exposed. The sacral promontory is exposed and the fifth disc located distally to the bifurcation of the aorta and vena cava. Gentle dissection is needed to avoid tearing the small vessels from the large ones. The soft tissues, with the autonomic nerves, are pushed aside and the median sacral artery may have to be ligated. The disc is kept exposed by four Steinmann pins covered with rubber drains, two above and two below the disc, as laterally as possible but without compressing the common iliac vein. The disc is opened in the middle, and stay sutures are applied to the two

the end plates are chiselled out as far as the posterior limbus, as a rule to a depth of 3 cm and until the cancellous bone is normal. Suction is

grafts can be calculated. A few pts develop hypotension during the lordosis positioning, and the anaesthetist should be warned that the intratracheal tube may slide down towards the carina, obstructing the main bronchus and causing atelectasis. Through a separate incision along the left iliac crest two, or in some cases three grafts are chiselled out at right angles to the crest, so

that the grafts comprise the entire thickness of the ala. Length and height have been measured beforehand. Again the patient is placed into a position of maximum lordosis, and the grafts are rammed in from the front by special rammers. During this procedure the assistant presses the overlying body backwards in cases of spondylolisthesis. When the lordosis position is

closed. A vitallium plate with two screws recreates the level of the iliac crest, and above this the periosteal edges and muscular aponeuroses are firmly sutured.

Postoperatively paralytic ileus is counteracted by injections of neostigmine during the first days. The patient is mobilized with a supporting corset in a few days. Pts with spondylolisthesis or fusion at two levels are treated with strict bed rest for 3 months and wear a supporting corset for at least 1 year. Vertebral and abdominal muscles are trained before ambulation. The final follow-up examination is carried out 3 years after the operation.

Most often the fifth disc was the object of surgery (Table 4). In 16 patients the operation involved the fourth as well as fifth disc, in one patient (spondylolisthesis) only the third lumbar disc.

Complications. The postoperative course was uneventful in 76 per cent. Eleven pts developed thrombophlebitis (Table 5), one has permanent oedema with a 4–5 cm increase in the circumference of the left leg and two patients have mild oedema (a 1 cm increase in circumference). Two cases of fatal pulmonary occurred, one of them about 48 hours after the operation in a patient who was otherwise in good health. The other patient had been disabled for years, bed ridden for 6 months, and had been slimming. She lacked initiative, was impossible to mobilize and died 5 weeks after the

Table 5 Complications

	No of pts	Sequelae No Yes
Thrombophlebitis	11	7 4
Pulmonary embolism	2	— 2 (died)
Infarct (but no phlebitis)	4	4 —
Pulmonary atelectasis	3	3 —
Pneumonia	1	1 —
Renal calculus (t.l.)	1	1 —
Neuritis of ulnar nerve due to pressure	2	2 —
Total	24	18 6
No complications	74=76%	

operation. This patient was among our first operated cases, and with our present experience we would now consider her too great a surgical risk. Experience has taught us to expend great energy on exercises to avoid thrombosis. Four pts developed mild pulmonary infarcts, but no clinical signs of phlebitis. Three developed severe atelectasis, but with no sequelae.

RESULTS

All the pts were seen at a clinical and radiological follow-up 3–8 years after the operation. If there was any doubt about whether or not solid fusion had been achieved, tomography was performed. Solid fusion was obtained in 86 out of 95 patients, viz., 90.5 per cent (three have died, one of them 17 months after the operation) (Figures 3 and 4). Solid union was obtained in 16 of the 17 disc spaces in which the grafts were inserted in the sagittal plane and in 85 of the 93 disc spaces in which the grafts were inserted in the frontal plane, i.e., in 101 out of 110 disc spaces or 91.8 per cent with no difference between the two techniques of insertion. Six of the 42 pts with spondylolisthesis (14.3 per cent) and three of the 53 with disc degeneration (5.7 per cent) did not show primary union. In spondylolisthesis the only stabilization is afforded by the inserted grafts. In disc

Table 4 Site of spine fusion

	37 men	61 women	Total 98	
LD 3	—	1	1	
LD 4	6	1	12	
LD 5	24	45	69	
LD 4+5	7	9	16	32 (discs)
Total	44	70	114	



Figure 3 X-ray showing solid fusion 7 years after operation on the 5th lumbar disc in a woman



Figure 4 Solid fusion of the 4th and 5th lumbar disc spaces 5 years after the operation in a woman of 45

operation additional stabilization is maintained by the pressure of the small joint spaces against each other posteriorly. Fifty pts wore a corset for at least 1 year 19 less than 6 months.

In nine pts solid union was not obtained three of them it was achieved by retraction from the front (right sided roach) and in three by posterior spondylodesis (Figure 5). In one laminectomy done (nerve root irritation) and in one extra disc segment was operated on from front.

At follow-up one-third of the pts were free of pain, one-third had constant and one-third occasional pain of varying duration (Table 6). Initially all the pts having constant low back pain wore a corset and were taking analgesics daily. More than half of the total material freed from back fatigue and had to rest up several times daily. Only 27 had sciatica, including 15 who also had had radiating pain prior to the operation. One underwent a

successful Gill operation (Gill & White 1955). Eleven had minor complaints from the donor site at the iliac crest, in six of them the metal had been removed.

At follow up 68 per cent were working (Table 7), but a few were receiving supplementary disablement pension. A total of 29 had been referred to rehabilitation centres, half of this number having been awarded disablement pension. A total of 37 were receiving disablement pension at the time of follow up as compared with nine prior to surgery.

Seventy three per cent considered themselves as cured or improved (Table 8). In 35 pts a possible somatic cause could be demonstrated as an explanation for a not completely satisfactory result, and in 24 cases psychological factors had influenced the

that the grafts comprise the entire thickness of the ala. Length and height have been measured beforehand. Again the patient is placed into a position of maximum lordosis, and the grafts are rammed in from the front by special rammers. During this procedure the assistant presses the overlying body backwards in cases of spondylolisthesis. When the lordosis position is straightened out, the two adjacent vertebral bodies grip around the grafts which thus become solidly fixed, their anterior edges behind the anterior edges of the vertebral bodies. The wound is closed. A titanium plate with two screws recreates the level of the iliac crest, and above this the periosteal edges and muscular aponeuroses are firmly sutured.

Postoperatively paralytic ileus is counteracted by injections of neostigmine during the first days. The patient is mobilized with a supporting corset in a few days. Pts with spondylolisthesis or fusion at two levels are treated with strict bed rest for 3 months and wear a supporting corset for at least 1 year. Vertebral and abdominal muscles are trained before ambulation. The final follow up examination is carried out 3 years after the operation.

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Total	44	70	114	

Table 7 Employment situation 3-8 years after the operation

	18 men	59 women	Total 95
Previous work resumed	19	36	55
Lighter work	8	9	17
Work later given up	4	3	7
Still working	23	42	65 (68%)
Referred for rehabilitation	17	12	29
			(14 disablement pensioners)
Disablement pension awarded	16	21	37
			(before op 9 pts)

Table 8 Patients' own evaluation of the result

	36 men	59 women	Total 95	
Cured	11	12	23	73 %
Better	15	31	46	
Unchanged	9	15	24	
Worse	1	1	2	

Table 9 Possible somatic explanation of an unsatisfactory result in 31 patients having constant pain at follow-up

	No of pts
Fusion of the body 9-21 mm ventrally (spondylolisthesis)	7
Not solid fusion	5
Narrowing of other lumbar discs	4
2-4 previous operations for slipped disc (positive myelogram)	3
Subsequent slipping of overlying disc	1
Subsequent obesity (99 kg 173 cm)	1
No somatic explanation for the pain	10
Constant pain	31
Preoperative history exceeding 10 years	16
Constant pain for more than 1 year preoperatively	31
Radiation to lower limbs	30
Totally incapacitated for more than 6 months before operation	14
Has not been working after the operation	13
Referred for rehabilitation after operation	13
Disablement pension, 8 men + 11 women (before operation 0 + 5)	19

Among 31 pts having constant pain we could find a possible somatic explanation in 70 per cent (Table 9). If in spondylolisthesis the fusion is performed with the vertebral body displaced too far anteriorly, a mechanical disproportion will persist, and if the body has been displaced forward under the overlying body, there is a predisposition to disc degeneration (Figure 6). Three had already undergone at least two operations for slipped disc and two myelographies using the locally irritant contrast medium Conray®. In 10 cases we found no somatic explanation for the pain, but in several cases hysterical neurosis has been diagnosed by psychiatrists.

Pts with constant pain had a particularly long history of preoperative pain, and practically all of them had sciatica. Inability to work was more common in this group, and even before the operation five had been receiving disablement pension, as compared with 19 or 61 per cent at follow-up.

Sixty per cent of the pts who had the operation when over the age of 45 were receiving disablement pension. The spine fusion had united in all but 7 per cent.

Some but not all pts were questioned about sexual potency, and none complained of impotence.

DISCUSSION

Technique Like Harmon (1963), Hodgson & Wong (1968), and Stauffer & Coventry

(1972), we used the extraperitoneal approach and did not have any difficulties or cases of paralytic ileus. The latter condition also does not seem to be a major problem in the transperitoneal technique (Sachs 1965, Debeyre & Dorat 1969, Freebody et al 1971).

Cortical grafts appear to give poorer union (Hodgson & Wong). Harmon has reported good results using sandwich grafts (cortical + cancellous bone), however, most authors use iliac grafts, as in the present series.

Harmon mobilized the pts from the day after the operation, Sachs and Stauffer & Coventry from the 3rd-4th day, Hodgson after a maximum of 14 days. Freebody et al immobilized their pts in bed for 4 weeks after fusion at one level, and cases with spondylolisthesis or multiple level fusion had 8 weeks in plaster followed by a moulded polyethylene jacket for another 3 months and thereafter an ordinary corset. Debeyre & Dorat immobilized the pts in bed for 3 months. Judging by the healing results, long immobilization does not appear to have led to any notable gain.

Results Harmon reported complete or partial relief of pain (clinically excellent or good results) in about 90 per cent of his 244 patients, 3-5 years after the operation. The results were related to the severity and extent of the radiological changes. Hodgson & Wong, Sachs, and Freebody et al have reported similar results, whereas Debeyre & Dorat obtained good results in 73 per cent. Stauffer & Coventry obtained clinically satisfactory results in only 36 per cent but their material comprised many patients who were having the operation for symptoms of pseudarthrosis following posterior fusion or instability following one or more laminectomies. Hodgson & Wong reported a greater relief from pain than would have been expected judging by the radiological healing result, although they achieved radiologically solid fusion in a very high percentage of cases, especially when using iliac grafts. Harmon obtained solid fusion in 95 per cent, Freebody et al in 84 per cent, and Debeyre &

Dorat in 76 per cent, whereas Stauffer & Coventry had solid healing in only 56 per cent of their unfavourably biased material. V obtained solid healing in 90.5 per cent, or 91.8 per cent of the fused discs, which we consider satisfactory.

Complications Deep vein thrombosis & other postoperative complications occurred less than 1 per cent of Harmon's patients. This must be ascribed to the energetic & early mobilization, as the patients were discharged within 9 days. Hodgson & Wong encountered deep vein thrombosis in two of 74 operated patients, Sachs in two out of 50 plus two cases of non fatal pulmonary embolism. Freebody et al recorded 11 per cent with deep vein thrombosis and the cases of pulmonary embolism among 2 operated patients (one fatal pulmonary embolus). Among 83 operated patients Stauffer & Coventry found three with deep vein thrombosis and one with pulmonary embolism, and Debeyre & Dorat recorded two cases of deep vein thrombosis among 1 patients plus two cases of pulmonary embolism. In our material we had two cases of fatal pulmonary embolism. This may have been a chance coincidence as the frequency of embolism in our Department is otherwise very low (one in more than 1200 operations for osteoarthritis of the hip), but in one of the cases it was due also to the indication for operation. We would not have done the operation today on this patient. We have not subsequently encountered this complication.

Cardiac arrest during the operation has been reported by Stauffer & Coventry and Freebody et al but without sequelae.

Only Stauffer & Coventry have reported the occurrence of anterior displacement of the inserted grafts (one case) requiring reoperation. Infection in the disc space arose in two of Stauffer & Coventry's patients and in one of Hodgson & Wong's.

The indications have varied and this has influenced the results. Stauffer & Coventry's series in particular differed from those of

others because of the particularly biased material.

The reason why this operation has not gained as much ground as it deserves is, apart from anxiety due to technical problems, the difficulty and uncertainty of the task of selecting pts who can be expected to achieve a satisfactory result. Harmon (1963) has demonstrated the importance of the organic changes being of sufficient severity judging by myelograms, X-ray motion films, and mature clinical consideration, as well as testing, during the operation, of the grade of disc degeneration by injecting saline solution into the disc space. Candidates for this operation usually have a long history of constant pain, and this is bound to affect them psychologically, so that many of them have neurotic symptoms, possibly inveterate neurosis, which can decisively affect the result. Therefore, Wilfing et al (1973) have suggested including psychological tests in the assessment. Our material confirms that mental disorders may aggravate the result, even when a definite cause of pain cannot be demonstrated clinically or radiologically. Patients who have not been relieved of pain go on consulting the orthopaedic surgeon unlike those who are free of pain, and this distorts the evaluation of the results, thus influencing his future attitude to the indications. Therefore, follow-up is necessary. Thereby, the result proves to be considerably better than assumed *a priori*, viz., three-quarters cured or definitely better and 68 per cent working, in a country with a highly developed social welfare service. In our opinion, this method of treatment is still justified, but its indications have now been further elucidated. In the future we shall be very restrictive in the case of patients over 45 years of age, as 60 per cent of them are awarded disablement pension after the operation. We shall try to evaluate the patients' psyche more closely before deciding upon an operation and shall exclude patients having

fixed neurotic symptoms. Reserve should also be displayed in operating on patients who have previously undergone one or more operations for disc herniation, as there may be nerve root adhesions. Patients with spondylolisthesis should be followed for at least three years, and if there is the slightest suspicion of incipient pseudarthrosis posterior spondylodesis by screws through the arch defects or some other form of fixation should be performed.

The decision regarding the indications for operation and the operation itself should still be in the hands of very experienced orthopaedic surgeons, and it must be emphasized that the postoperative management, especially the prevention of thrombosis, makes great demands upon the staff.

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FIXATION OF PELVIC FRACTURES AND DISLOCATIONS

An Experimental Study on the Loading of Pelvic Fractures and Sacro-Iliac Dislocations after External Compression Fixation

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A trapezoid external compression fixation frame assembled with 6 Hoffmann instruments, was used for stabilizing experimental injuries to the pelvic skeleton of ten cadaver specimens. The resistance to loading in position corresponding to upright standing was tested in 17 experiments and related to the calculated load *in vivo*. The results indicated that

compression frame well enough to permit weight bearing in the upright standing position. Bilateral injuries to the pelvic skeleton, vertical and oblique, could not, however, be stabilized enough to resist more than a fraction of the normal load in the upright standing position.

Key words: dislocation, fracture fixation, loading, pelvic bones, sacro-iliac joint, stability

Accepted 23 XI 77

The pelvis owes its stability to the circular arrangement of the individual bones forming the pelvic ring, to the strong interosseous ligaments between the sacrum and the ilium and to the pubic symphysis. The vertical load on standing is taken up by the sacrum which moves and rotates downwards and forwards. Due to its wedge-shape it becomes compressed between the iliac bones. Simultaneously the sacro-iliac ligaments tighten and add to the stability (Weisl 1954, Kopsch 1955, Solonen 1957, Hollinshead 1969).

The uneven articular surfaces of the sacro-iliac joint make possible an interlocking which

is supposed to reinforce the stability of the pelvic ring particularly when this is loaded on standing (Weisl 1954).

In rupture, dislocation and/or fracture of the pelvic structures the stability of the pelvic ring becomes disturbed and the ultimate aim in treatment is to restore the stability by an accurate consolidation of the dislocation and/or fracture as possible. This is particularly important in fractures of the posterior, weight-bearing areas as injuries in this region more often lead to persistent instability than is the case for fractures in the anterior region.

Conservative measures such as bed rest slings and plaster have for a long time been the accepted mode of treatment in these fractures but recently external fixation with the use of Hoffmann instruments has been advocated (Caraballona et al. 1973, Connes 1973 Slatas & Karaharju 1975).

In an experimental study Slatas & Karaharju (1975) demonstrated that compression osteosynthesis of posterior pelvic fractures was best obtained by a trapezoid frame and bar mounted with an inclination of 70° to the long axis of the body. The frame is attached to three pins inserted into each iliac wing. The trapezoid compression frame offers an acceptable fixation of dislocations and fractures of the posterior parts of the pelvic ring but whether this fixation gives sufficient stability to allow weight bearing in the standing position is not known. We consider this to be an important aspect as early mobilization could then be instituted with the compression frame in place. We have therefore carried out an experimental study to analyse the amount of load different posterior fractures and dislocations can take after being fixed by the trapezoid compression frame.

MATERIAL

Ten cadaver pelvis were used (Table 1). They consisted of the pelvic ring with the fifth lumbar vertebra and had been cleaned of soft tissues excluding the ligaments. The specimens originated from patients who had died of diseases that did not involve the skeleton. In three cases, the medical records could not be obtained. On naked eye examination the pelvic specimens did not disclose any signs of disease. A total of 17 loading experiments were performed on the ten specimens, in which dislocations and fractures had been produced prior to loading. To obtain sacro-iliac dislocations all the sacro-iliac ligaments and the symphysis were cut. Fractures were produced by chiselling through the sacrum or the ilium and through the pubic ramus in the desired direction (see Table 2).

Unilateral injuries

Ten loading experiments were performed in five there was a dislocation of one sacro-iliac joint and the symphysis. In the other five there were fractures of the sacrum or ilium combined with fractures of the pubic ramus (Table 2).









Bilateral injuries

Seven loading experiments were performed in two there were bilateral dislocations of the sacro-iliac joints and the symphysis, in three there were

Table 1 Specimens used for experimental injuries to the pelvic skeleton and subsequent external compression fixation

Specimen no.	Age	Sex	Weight, kg	Diagnosis
1	65	M	—	—
2	66	M	74	Liver cirrhosis and acute pyelonephritis
3	67	M	69.5	Nephropathia with uraemia
4	69	M	74	Myocardial infarction
5	71	M	81	Cancer of the thyroid with metastasis of the liver and lymph nodes
6	72	F	—	Cerebral thrombosis
7	73	F	69	—
8	77	F	74	—
9	77	F	67	Pulmonary embolism cancer of the uterus
10	82	M	47	Pulmonary embolism, myocardial infarction, acute pancreatitis

Table 2 *Experimental injuries of pelvic specimens*

Unilateral injuries		Bilateral injuries	
Injury	Nos	Injury	Nos
	5		2
	3		3
	1		1
	1		1





bilateral fractures of the sacrum and pubic rami and in two unilateral iliac fracture and contralateral dislocation of the sacro-iliac joint combined with fractures of the pubic rami or sectioned symphysis (Table 2)

METHODS

To achieve stability of the pelvic girdle an external compression frame assembled with the Hoffmann instruments was employed (Connes 1973). The mountings were anchored to the pelvic girdle with three pins inserted into each iliac crest. The parts of the pelvic girdle were readapted and compression exerted by a compression bar ■ part of a trapezoid compression frame with the connector bars inclined to the long axis of the body ■ 70° as described by Slatis & Karaharju (1975).

As a preamble to the loading tests the compressive force exerted by the Hoffmann instruments at the site of injury was measured. In two cases with unilateral dislocation of the sacro-iliac joint and symphysis and in two cases with unilateral fracture of the sacrum or ilium or pubic rami (Table 3) small mercury filled rubber balloons were inserted between the dislocated or fractured surfaces. The balloons were connected to a horizontal cylinder each containing an indicator piston. Compression of the pelvis squeezed mercury into the cylinder and caused movement of the piston, counterpressure was then exerted via a movable vertical tube, filled with mercury and a movable vertical tube, filled with mercury and an indicator mark on the piston returned to its initial position (cf Slatis & Karaharju 1975). The compression was registered near maximum obtainable compression when the individual components of the frame started bending.

Table 3. Compression obtained with external compression fixation of injuries to the pelvic skeleton

Specimen no	Injury	Compression of the posterior arch, kPa	Compression of the anterior arch, kPa
7		145	116
8		143	117
9		4*	85
10		177	35

* Fracture with dislocation of the fracture, in contact only at its lower part.

The loading experiments on the specimens, stabilized by the external compression fixation, were performed in a standard external testing machine (Alwetron Model T-2105) with a compression speed of 5 mm per minute (cf. Gunterberg et al. 1976). The pelvic tuberosities of the anterior pubic rami of the specimens were fixed in two separate blocks of epoxy resin ('Paxall-ding'), one for each side, in a position corresponding to upright standing (Figure 1). The load and time were registered on an extensometer. A hypothetical load in upright standing was calculated according to Nachreiner & Elfrink (1969).

RESULTS

The compressive forces obtained in the area of injury in the posterior and anterior arches of

the pelvic girdle are presented in Table 3. In specimen 9 the fracture of the ilium was not totally reduced and thus compression was only obtained on its caudal part, whereas the corresponding fracture was reduced and not compressed.

The results of the load were also shown in Tables 4 and 5. Graphs representing the load were also shown in Figure 2.

Comments

Group 1 specimens with unilateral dislocation of the anterior arch and symphyseal

fracture were a gradual reduction of the anterior arch noted when approximately

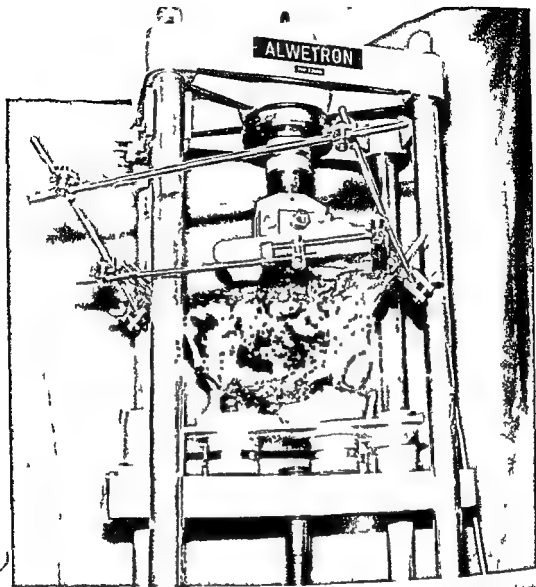


Figure 1 Specimen with the trapezoid external compression frame under load in material testing machine

one third of the ultimate acceptance of load was reached

Group 2 Specimens with unilateral fractures of the sacrum or ilium and the pubic rami

In these cases a slight gradual dislocation took place when the posterior fracture was vertical but not when the fracture was oblique. In the latter case the pelvis was almost stable until the ultimate acceptance of load. At this time a fracture developed on the opposite side





Group 3 Specimens with bilateral dislocation of the sacro-iliac joint and symphysis.

In these cases a gradual dislocation of the sacro-iliac joint started from the onset of loading

Group 4 Specimens with bilateral fractures of the sacrum or ilium and the pubic rami.

As in Group 2 a gradual dislocation took place during loading when the fractures were vertical. Oblique fractures combined with contralateral dislocation of the sacro-iliac

4a. Results of external compression fixation of unilateral experimental injuries to the pelvic skeleton

Specimen no	Injury	Ultimate acceptance of load, N	Calculated load in upright standing, N
1 } 2 } 6 } 7 } 8 }		1962 1530 657 1207 1597	951 1108 <hr/> 961 922
3 } 4 } 10 }		1540 2452 2695	1010 1020 624
5		2950	1020
9		1177	824

Compression only exerted on caudal part because of dislocation of the iliac fracture





did not resist loading better than vertical fractures.

Conservative treatment by balanced traction or plaster fixation can to a certain extent reduce the fracture, but if the hemipelvis is grossly displaced, recurrent dislocation is apt to occur. Raf (1966) reported a high incidence of persistent pelvic asymmetry and low back pain at follow-up of patients with double vertical fractures.

of the pelvis constitute some 3 per cent of all fractures. Traffic accidents and falls from heights are the causative factors. The severity of the impact is great. It has been found that 200 - 1000 kp (1962 - 1963) are necessary to disrupt the pelvic girdle (Colachis et al 1963). When the pelvis becomes fractured, the loss of stability is great, if the posterior, weight-bearing part of the pelvic girdle is involved. The stability can at times be equalled to flailness.

Recent development of the armamentarium for external fixation of fractures has opened up new possibilities for the treatment of unstable pelvic fractures. Preliminary reports by Connes (1973) and Slatas & Karaharju (1975) indicate that external fixation of the pelvis not only stabilizes the fracture but also provides a great relief from pain.

Table 4b Results of external compression fixation of bilateral experimental injuries to the pelvic skeleton

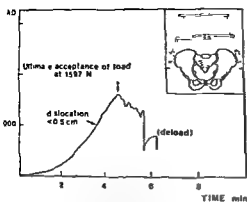
Specimen no	Injury	Ultimate acceptance of load, N	Calculated load in upright standing N
6 } 7 }		50 102	— 951
3 } 4 } 10 }		118 353 471	1010 1020 624
8		422	922
9		216	824

injured area Based upon clinical experience, the time of recumbency advocated after external fixation of the fracture has been 3 weeks, but so far no firm evidence regarding the load acceptance of different pelvic injuries treated by external fixation has been available

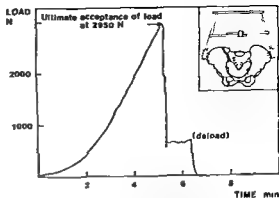
The experimental data obtained in the present investigation show that the external trapezoid compression frame stabilizes the pelvic girdle so that it can resist vertical load forces on the sacrum surprisingly well The load tolerance is, however, closely related to the type of skeletal injury present It is the unilateral injuries which can best resist vertical loading after compression fixation A fracture through the sacrum or the ilium is more stable than a dislocation through the sacro-iliac joint

Furthermore an oblique fracture through the posterior arch is more stable than a vertical one The reason for this can be found in the articular surfaces of the sacro-iliac joint which are slippery and difficult to reduce into a locked position The rugged surfaces of fractures appear to have better interlocking properties Bilateral injuries, in which the hemipelvis is detached from the cranium on both sides, remain — as may be expected — unstable for vertical load despite the compression device The frame is here merely maintaining the position of the reduced part of the pelvis.

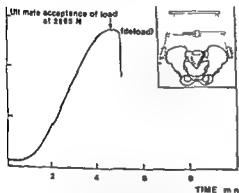
The body weight was known in eight of the ten cases for this investigation making it possible to calculate the normal load on the L V vertebra in the upright standing posture



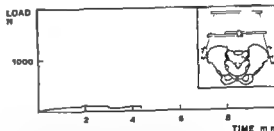
Specimen no 8 The calculated normal load in the sitting position was 922N



C Specimen no 5 The calculated normal load in the upright standing position was 1020N



Specimen no 10 The calculated normal load in the upright standing position was 624N



D Specimen no 6 The normal load could not be calculated but without doubt far exceeded this very low acceptance of load

Figure 2 Load time diagrams for pelvic specimens with different types of injury (see insets)

(Johansson & Elfström 1970) It has been found that the load varies depending on movements, etc. On slow walking the load increased by about 15 per cent and on running by 40 per cent and finally on straining in erect posture by about 50 per cent. Our method of supporting the loaded vertebrae by separate blocks of epoxy resin has several practical reasons not been quite physiological as the load is normally taken up by the hip joints. The results mainly give an indication of the resistance to loading when a load has been applied to an experimental pelvis.

In the present series, the ultimate load in unilateral lesions well surpassed

the calculated values for vertical load on the pelvis during physiological conditions. In bilateral lesions, on the contrary, the resistance to vertical load was far below the calculated load in the erect position. These findings suggest that in unilateral lesions partial or full weight bearing may be instituted immediately after application of the frame, whereas in bilateral lesions weight-bearing should be postponed for several weeks. In these experiments the stabilizing effect of muscular activity and the possibility of partly intact sacro-discal ligaments in pelvic disruptions *in vivo* have not been given due consideration.

Hence, correlations with clinical conditions

should be made with due caution. On the other hand, calculations regarding the physiological load in the upright position and the data obtained warrant certain conclusions which are applicable to clinical conditions. Thus, in lesions of the posterior and anterior arch of the pelvis, properly reduced and stabilized with the trapezoid compression frame, it may be suggested

that in bilateral injuries no weight bearing should be permitted before the already suggested 3 weeks of immobilization.

that the above recommendation also includes unilateral sacro-iliac dislocations and unilateral vertical fracture of the sacrum or iliac wing weight bearing by crutches is possible.

that in unilateral injury involving oblique fracture of the sacrum or iliac wing early mobilization with full weight bearing may be instituted.

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ERYTHROCYTE SEDIMENTATION RATE IN INFECTED AND NON-INFECTED TOTAL HIP ARTHROPLASTIES

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The postoperative course of the erythrocyte sedimentation rate (ESR) following total hip replacement was studied in 18 patients with delayed infections and compared with the course in 75 uncomplicated cases. Normally, the ESR returned to the preoperative level in 3-6 months, but in delayed infections it was significantly increased already during the first postoperative months, and never returned to normal levels. There was also a small but significant difference between the preoperative values in the two groups, which in women may be explained by a pre-existing infection in the hip

Key words hip, arthroplasty, infection, erythrocyte sedimentation rate

Accepted 27.xii 77

The early wound infections following total joint replacement cause the same local and systemic symptoms and signs as other wound infections during or shortly after the wound-healing stage, and are therefore unlikely to be overlooked. On the other hand, delayed infections that give symptoms months or years after the operation may be difficult to detect. The erythrocyte sedimentation rate (ESR) seems, in this respect, to be a simple and valuable asset (Carlsson et al 1977, Muher et al 1973, Reichelt & Brand 1974).

Since total hip arthroplasty was introduced into the Department of Orthopaedic Surgery at Malmö General Hospital in 1968, measurement of ESR has become a routine procedure in the laboratory investigation of all patients operated upon and at every visit to the out-patient clinic.

This investigation describes the normal

course of the ESR after uncomplicated total hip replacements, and compares it with the course in patients with a normal early postoperative wound healing but who subsequently prove to have a delayed infection

MATERIAL AND METHODS

The ESR was performed by the Westergren method. Böttiger & Svedberg (1967) suggested the following normal ranges (mean \pm 2 s.d.)

	Men	Women
< 50 years	0-13	0-21 mm
> 50 years	0-19	0-28 mm

The material consisted of two groups of patients. In both groups, patients with rheumatoid arthritis, pelvispondylitis or with any other known cause of an elevated ESR were excluded.

Group A

Seventy-five patients, 51 females and 24 males, underwent total hip replacement, according to Charnley at the Malmö General Hospital. The ages of the females ranged from 42 to 79 years (mean 65 years). Only two women were less than 50 years old—42 and 48 years, respectively. The

should be made with due caution. On the other hand, calculations regarding the physiological load in the upright position and the data obtained warrant certain conclusions which are applicable to clinical conditions. Thus in lesions of the posterior and anterior arch of the pelvis properly reduced and stabilized with the trapezoid compression frame it may be suggested

- that in bilateral injuries no weight-bearing should be permitted before the already suggested 3 weeks of immobilization.
- that the above recommendation also includes unilateral sacro-iliac dislocations and unilateral vertical fracture of the sacrum or iliac wing weight bearing by crutches is possible,
- that in unilateral injury involving oblique fracture of the sacrum or iliac wing early mobilization with full weight bearing may be instituted.

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symptomatology it should be possible to differentiate them from delayed infections. Furthermore, the inflammatory reaction caused by surgery should have disappeared and the ESR returned to normal when a joint is hit by a hematogenous infection a reasonably long time after the operation (Ahlberg et al., in press). On the other hand, if the bacteria are implanted at the operation, there should be some signs of inflammation from the outset that do not disappear until treatment is instituted.

In 14 patients with "late" infections following total hip replacement, Reichelt & Brand (1975) not only observed a significantly elevated ESR already from the first postoperative month, but also that the ESR never returned to normal. Seeing that the same phenomenon was found in the present investigation, there is strong evidence that delayed infections are caused by bacteria implanted in the wound at operation.

The evaluation of an ESR necessitates a knowledge of its course following uncomplicated total hip replacements (a factor that seems to be of special importance during the first postoperative year).

The investigation of Reichelt & Brand (1975) showed that all males had an ESR below 20 mm, 93 per cent of the females an ESR below 30 mm and 100 per cent of the females an ESR below 40 mm, 6-12 months postoperatively in uncomplicated total hip replacements. In 147 uncomplicated total hip replacements, Mulier et al. (1973) found that within 4 months the ESR normalized in 93 per cent. In the remaining 7 per cent, the ESR normalized within 1 year postoperatively.

From the present investigation one can conclude (Figure 1) that an ESR of 40 mm or more, more than 3 months postoperatively strongly indicates a deep infection even if the patient is still free from symptoms, and radiographic signs of infection are absent. The statement only holds true when other diseases with elevated ESR and complications such as urinary tract infection or pneumonia are excluded.

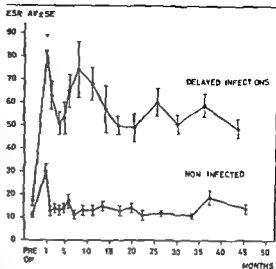


Figure 1 The course of the ESR \pm SE in uncomplicated total hip arthroplasties compared with its course in delayed infections

The ESR was not checked until 1 month postoperatively. During the first 2 or 3 weeks, the level is not only influenced by the surgical trauma or by infection but also by other treatments, e.g., Dextran 70 infusions (Arthurson & Wallenius 1964, Rø & Kluge 1971).

The preoperative ESR must also be considered. In this investigation no patient in the non-infected group had an ESR of more than 15 mm above the preoperative value 6 months postoperatively—the highest value being 34 mm. The ESR was also determined 2-3 months postoperatively in 58 of the 75 non-infected cases. At no stage did it exceed the preoperative value by more than 21 mm.

The difference between the preoperative values in the infected and non infected group is remarkable. In females, but not in males, this difference may be explained by a pre-existing low-grade infection contracted at a previous operation. Thus, in males a higher ESR, even within the normal limits, for no understandable reason coincides with a higher rate of infection.

With a knowledge of the normal course of the ESR following total joint arthroplasty, it

should be possible to diagnose the infection at an earlier stage. However, it is still necessary for 2 to 3 years to elapse after surgery before statements concerning the incidence of infection are made. One reason for this is that most hematogenous infections occur at a late stage (Ahlberg et al. in press). Another reason is that in rheumatoid arthritis and other conditions with elevated ESR, the evaluation of the actual ESR is difficult, necessitating a reliance on other diagnostic methods such as radiography and scintigraphy.

Every patient in group II experienced pain, but the time of onset, average 10 months, must be considered uncertain, seeing that the debut is seldom, if ever, acute. On the contrary, in most cases slowly increasing pain in the thigh or groin is the first sign. Furthermore, one gets the impression that many patients with delayed infection never become completely symptom-free postoperatively, and, indeed, some never manage to walk without a stick.

A definite correlation between elevated ESR and postoperative pain was found by Mulier et al (1973).

ESR is a simple and reliable laboratory method. As an elevated ESR may be the first sign of an infection, it is recommended that the method be included in the routine procedures at every examination of a patient undergoing total joint replacement.

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LATERAL DISLOCATION OF THE PATELLA FOLLOWING MARMOR AND GUEPAR ARTHROPLASTY OF THE KNEE

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The follow up of 50 knees treated with the modular Marmor prosthesis and 50 with the Guepar hinge joint included tangential radiography of the femoro-patellar joint. After Marmor arthroplasty lateral patellar dislocation was found in seven knees, in six causing pain. After Guepar arthroplasty lateral patellar dislocation was found in 32 knees, but pain was present in only three. There was only a questionable correlation between pre-existing valgus deformity and postoperative lateral patellar dislocation, and an external rotation deformity of the lower leg was found in only five cases after Guepar arthroplasty. Thus, neither phenomenon could explain the high incidence of lateral patellar dislocation in the Guepar series. These dislocations must be assumed to be due to the unphysiological strain on the extensor apparatus inherent in this type of prosthesis.

Key words: knee, arthroplasty, patella, dislocation

Accepted 21.7.78

Dysfunction of the femoro-patellar joint is now assumed to be the most common cause of poor primary results following arthroplasty of the knee (Deburge & Guepar 1976, Engelbrecht et al 1976, Insall et al 1976, Marmor 1976). Some of these poor results appear to be due to dislocation of the patella, but the incidence of this complication is still largely unknown and apparently depends to some extent upon the type of knee prosthesis.

The object of the present study was to elucidate the incidence of femoro-patellar dislocation, and the associated pain, following knee arthroplasty using the Marmor modular prosthesis and the Guepar hinge joint.

MATERIALS AND METHODS

The material comprises 100 knee arthroplasties, 50 by the Marmor and 50 by the Guepar method, performed in the Department of Orthopaedic Surgery U, Rigshospitalet, University of Copenhagen, during the period 1974 to 1977.

During the study period the two types of arthroplasty were used as complementary methods. In cases of less severe articular destruction the Marmor knee was used, in cases of advanced destruction with severe contracture or deformity the Guepar knee was preferred.

In both methods the technique of opening and closing the knee was in principle the same. The approach was in all cases via a long straight, medial parapatellar incision, extending proximally into the quadriceps sponcrous close to its

Table 1 Grading of the lateral patellar dislocation

Grade	Patellar dislocation
0	None
1	< $\frac{1}{2}$ patellar width
2	$\frac{1}{2}$ —1 patellar width
3	> 1 patellar width

junction to the vastus medialis. In all cases of rheumatoid arthritis, synovectomy was carried out. In closing the wound, the quadriceps aponeurosis and joint capsule were carefully sutured using non-absorbable knotted sutures. Postoperative mobility training was started on the 1st day, and walking with full weight-bearing began on the 10th day.

Out of 50 consecutive Marmor arthroplasties 13 were performed on men and 37 on women. The age range was 18 to 82 years, mean 61. The underlying disease was rheumatoid arthritis in 29

mean 14 months.

Of the 50 consecutive Guepar arthroplasties 18 were performed on men and 32 on women. The age range was 28 to 86, mean 65 years. The underlying disease was rheumatoid arthritis in 37 cases, osteoarthritis in 10, and posttraumatic arthrosis in three. The patients had been followed up for 3 to 25 months, mean 10 months.

In all cases the follow-up included radiological examination with tangential exposure of the femoro-patellar joint. Displacement of the patella, if present, was graded on a scale from 0 to 3 (Table 1). A direct comparison with the preoperative X-ray appearances was not possible as far as the tangential view was concerned, as this was not a routine procedure at the beginning of the period under study.

RESULTS

Following Marmor arthroplasty patellar dislocation was found in seven knees, grade I in six and grade II in one. However, in the latter case the dislocation had been present also preoperatively, but no attempt had been made to correct it because of severe dysplasia of the femoro-patellar joint. Thus, following 50 Marmor replacements there were six patellar

Table 2 Grade of lateral patellar dislocation: relation to pain in 50 knees treated with the Marmor prosthesis

Grade of dislocation	Pain			Total
	None or negligible	Moderate	Severe	
0	33	9	1	43
1	1	5	0	6
2	0	1	0	1
3	0	0	0	0
Total	34	15	1	50

Table 3 Grade of lateral patellar dislocation: relation to pain in 50 knees treated with the Guepar prosthesis

Grade of dislocation	Pain			Total
	None or negligible	Moderate	Severe	
0	18	0	0	18
1	12	0	1	13
2	12	0	2	14
3	5	0	0	5
Total	47	0	3	50

dislocations (12 per cent) which could be related to the surgical treatment. Dislocation related to pain is shown in Table 2. Pain was present in six out of seven knees with patellar dislocation but in only 10 of the remaining 43 that did not have dislocation.

After Guepar replacement patellar dislocation was found in 32 (64 per cent) out of 50 knees. Among these dislocations 13 were grade I, 14 grade II, and five grade III. Within the Guepar series there was no recognized case of preoperative patellar dislocation. Dislocation related to pain is shown in Table 3. Pain was present in three of the 32 knees with patellar dislocation, but in none of the remaining 18 without dislocation.

The difference in the incidence of lateral patellar dislocation between knees having

Marmor (12 per cent) and Guepar (64 per cent) arthroplasty is statistically significant ($P < 0.02$).

DISCUSSION

The Marmor and the Guepar series do not differ essentially in sex ratio, age distribution, underlying disease, follow-up period, surgical approach, or postoperative management. On the other hand, they differ in two other respects. The Guepar series comprises cases having relatively severe destruction of the joint (cf the indications), and the two types of prosthesis are entirely different in their action in the biomechanics of the femoro-patellar joint.

The relatively severe articular destruction, in particular the presence of pronounced preoperative valgus deformity, might be imagined to be responsible for the high incidence of patellar dislocation in the Guepar series. It has been reported that knees with severe valgus deformity of long standing may develop lateral patellar dislocation following surgical correction of the deformity owing to taut lateral retinaculum (Weckström et al 1976). In order to elucidate this aspect, the incidence of dislocation is related to the presence of preoperative valgus deformity in Table 4.

It will be seen that although the incidence of dislocation was indeed somewhat higher after correction of severe valgus deformities, lateral dislocation of the patella was almost as high among knees without valgus angulation as in the Guepar series as a whole. Thus, pre-existing valgus deformity did not essentially influence the postoperative incidence of dislocation.

If the Guepar prosthesis is inserted in cases with an external rotation deformity of the lower leg there will be an increased tendency for lateral dislocation in relation to the lateral displacement of the insertion of the patellar ligament. The present series included five cases with such a deformity ranging from 20° to 30° . Only three of them developed lateral patellar dislocation. Therefore, external rotation deformity of the lower leg cannot have markedly influenced the incidence of dislocation in the Guepar series.

The weakening of the vastus medialis involved by the medial parapatellar approach has possibly been the cause of the relatively few and slight dislocations in the Marmor series. Since, however, this factor is the same in the Marmor and in the Guepar series, it cannot *per se* be an explanation of the increased incidence of dislocations among the Guepar operated patients.

Weckström et al (1976) and Deburge & C (1976) have shown that the Guepar

is an unphysiological design of the femoral shield of the prosthesis which does not sufficiently support the lateral articular surface of the patella (Figure 1). Moreover, the shield causes a slight forward displacement of the patella. Combined with the fact that the axis of flexion in the Guepar prosthesis is localized rather far posteriorly, this means great stress upon the extensor apparatus during flexion of the knee.

Patellar dislocation following Guepar arthroplasty does not seem to give rise to major pain in the short term (cf Table 3). This must be due to the mechanical function of the femoral shield which secures a

Table 4 Preoperative valgus deformity of the knee in relation to type of arthroplasty and to the incidence of lateral dislocation of the patella at follow-up

	Degrees of valgus deformity			Total
	0-5	10-15	>15	
Marmor				
Patella in situ	23	16	4	43
Patella dislocated	2	4	1	7
Guepar				
Patella in situ	13	4	1	18
Patella dislocated	18	6	8	32
Total	56	30	14	100



Figure 1 Tangential view of the femoro-patellar joint following Guepar arthroplasty. Note the unphysiological shape of the femoral shield and the lateral patellar dislocation typical of the Guepar prosthesis.



Figure 2 Tangential view of the femoro-patellar joint 8 months after Guepar arthroplasty. Note the lateral patellar dislocation and severe erosion of the patellar joint surface. The patient has satisfactory articular function and no pain.

reasonable sliding function regardless of appreciable incongruence against the articular surface of the patella and regardless of an occasionally severe secondary malformation of the patella (Figure 2). This is unlike the findings after Marmor arthroplasty in which even rather minor dislocation of the femoro-patellar joint, with which the arthroplasty does not otherwise interfere, apparently cause pain in most cases (cf. Table 2).

Patellar dislocation is not always recognized by conventional clinical and radiological examination, and often it is demonstrable only on a tangential view of the femoro-patellar joint. Therefore, patellar dislocation should be considered as a possible cause of persistent pain in the knee following arthroplasty.

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RADIOLOGICAL DIAGNOSIS OF LATERAL LIGAMENT LESION OF THE ANKLE

Comparison Between Talar Tilt and Anterior Drawer Sign

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In a prospective study of 244 patients with ankle lesions a comparison between the talar tilt and the anterior drawer sign was made, leading to the following conclusions:

Ligament lesions which are not disclosed by the talar tilt examination may be diagnosed by the anterior drawer sign. The anterior drawer sign cannot be diagnosed by the talar tilt examination. The two methods are complementary in the diagnosis of the lateral ligament lesions of the ankle.

Key words: ankle joint, anterior drawer sign, ligament injuries, talar tilt

Accepted 17.1.78

Ruptures of the lateral ligaments of the ankle are best diagnosed by arthrography (Muller et al. 1965, Fulp 1973). However, this method is not generally accepted. In the orthopaedic departments, ligament lesions of the ankle are diagnosed by the instability of the ankle - the talar tilt - provoked by forced inversion of the foot (Rubin & Witten 1960, 1965).

During the last few years some authors have recommended examination of the instability of the ankle - the anterior drawer sign - for the diagnosis of such lesions (Castaing & Delplace 1972, Larsen et al. 1970, Lindstrand & Mortensson 1976).

In order to compare these two methods - the talar tilt and the anterior drawer sign - a comparative investigation was made in an attempt to answer the following questions:

1. Can the anterior drawer sign disclose ligament lesions which are not revealed by

the talar tilt, or *vice versa*?

2. Can the anterior drawer sign replace the talar tilt as a means of diagnosis?

3. Is it possible to differentiate between an isolated lesion of the anterior talofibular ligament and a combined lesion of the anterior talofibular and the calcaneofibular ligaments by the two methods?

MATERIAL AND METHODS

The series studied consisted of 244 patients with recent ankle injury. All the patients were seen within 24 hours of the trauma. In all cases a lateral ligament lesion was suspected clinically. None of the patients showed radiological signs of a fracture. Radiological measurements of the talar tilt (TT) and the anterior drawer sign (ADS) were made in all cases.

Throughout the period concerned both examinations were performed using the same



Figure 1 The difference in the distance between the articular surfaces of the talus and the tibia at the level of the top of the lateral trochlea tali on the injured (left) and on the normal (right) side

technique The TT examination was performed with the investigator placed on the contralateral side of the foot to be examined. With the left/right hand fixing the leg just above the ankle and the right/left hand fixing the heel, the foot was supinated with maximal force. An anteroposterior exposure, centred on the middle of the ankle joint, was made on both sides, the unaffected foot always being examined before the injured one. The distance between the articular surfaces of the talus and the tibia was measured at the level of the top of the lateral trochlea tali on the exposures of the injured and the unaffected sides (Figures 1 and 2) and the difference in the tilted position on the two sides was calculated.

The ADS examination was performed with the leg elevated, supported at the popliteal fossa and the heel, in such a position that the thigh was horizontal, and the foot rotated 30° medially (The support at the popliteal fossa is very important, otherwise the weight of the leg alone may provoke a subluxation in the ankle joint.) With the beam placed horizontally, an X-ray exposure, centred just above the tip of the malleolus, was

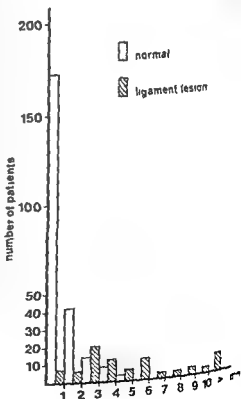


Figure 2 The difference in the distance between the articular surfaces at the level of the top of the lateral trochlea tali at rest and in forced supination in 244 normal ankles and in 85 ankles with surgically verified ligament lesions



Figure 3 Double exposures showing the position of the posterior margin of the tibia and of the posterior process of the talus before and after loading on the injured (left) and normal (right) side

made. After this, the leg was loaded with a 5 kg weight just above the ankle joint, and after the patient had relaxed completely, a new X-ray exposure was made on the same film with the X-ray equipment and the foot in exactly the same position. Both feet were examined, the unaffected always before the affected one. The displacement of the posterior margin of the tibia in relation to that of the posterior process of the talus between the two exposures was measured on the injured and unaffected sides (Figures 3 and 4) and the difference in displacement on the two sides was calculated.

Radiologically, a diagnosis of ligament rupture was made when the difference between the injured and the unaffected sides was 3 mm or more according to the TT examination and/or when the difference in displacement on the two sides was 2 mm or more according to the ADS examination.

In the event of a positive finding the patient was usually subjected to operation with the aim of suturing the ruptured ligaments. Patients with pronounced discrepancy between the clinical and radiological findings were referred to the outpatient department. If ligament rupture was still suspected after re-examination about 1 week after the trauma, these patients were treated with a plaster cast. Patients with normal radiological findings and without definite clinical suspicion of ligament rupture were regarded as having a simple sprain and were discharged immediately.

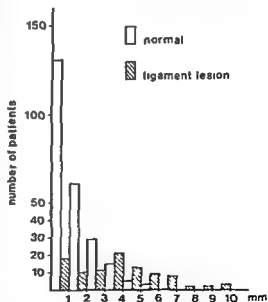


Figure 4 The displacement of the posterior margin

with surgically verified ligament lesions

In the period from Oct 1 to Nov 30, 1976, all the examinations were assessed and almost invariably performed by the same investigator. In the few cases where this was not possible, the TT examination was performed by a doctor from the emergency ward, while the ADS examination was performed by an X-ray technician. In this period, doubtful cases and technical problems were often discussed with the staff. In the period from Dec. 1, 1976 to Feb 15, 1977, the examinations and assessments were made routinely. In this period, the TT examinations were performed by doctors from the emergency ward and the ADS examinations by X-ray technicians, while doctors from the X-ray department assessed the findings.

In the final analysis of the series all X-ray films were reappraised and all hospital records were reviewed as regards symptoms, clinical and operative findings.

RESULTS

Ninety-six patients were discharged immediately with simple sprain. None of these patients showed signs of ligament rupture on TT examination. In three cases, a rupture of the ligaments was suspected on ADS (difference in displacement 2–2.5 mm). In two of these, this finding was overlooked primarily because of wrong measurement. In the third case, the surgeon found no indication for operation in spite of the radiological finding (Table 1).

Sixty-two patients were transferred to the outpatient department. After repeated clinical examination and, in some cases, repeated radiological examination (which is not included in the report), 42 of these patients were treated for ligament rupture with a plaster cast for 6 weeks. Twenty were regarded as having a simple sprain (Table 2).

Table 1 The radiological diagnosis in 96 patients with simple sprain
Talar tilt investigation

Radiological diagnosis	Normal	Ligament lesion	Total
Normal	93	0	93
Ligament lesion	3	0	3
Total	96	0	96

One patient with a falsely positive TT finding was checked radiologically. The first examination had revealed a distance between the articular surfaces of 6 mm on the injured side and of 3 mm on the unaffected side. In the repeat exposure, the corresponding figures were 0 and 5 mm, respectively.

Eighty-six patients were subjected to operation because of suspected ligament rupture. At operation, ligament rupture was found in 85 of these patients, while the ligaments were intact in one (displacement difference 3 mm by ADS). In two cases, only a capsular lesion was found (in Table 3 these are recorded as a lesion of the anterior talofibular ligament). In three cases, both investigations were negative. Of these patients, two were operated on because of severe clinical symptoms of ligament rupture. In both cases, a rupture of the anterior talofibular ligament was found. The third patient was subjected to operation because of a primarily erroneous measurement, in this case a capsular lesion was found (Table 3).

During the period from Oct 1 to Nov 30, 1976, the TT and ADS examinations showed almost the same efficiency. During the subsequent period (Dec 1, 1976–Feb 15, 1977) a marked decrease in the efficiency of ADS was observed (Table 4).

DISCUSSION

In both investigations the purpose is the same, to disclose a ligament rupture by demonstration of instability of the talus. In either instability in the frontal plane (TT) or in the sagittal plane (ADS). It is well known that the degree of TT present in the normal ankle is highly variable (Rubin & Witten 1960). This was confirmed in the present series. Moreover, a great variability in the degree of ADS was found. Because of this variation in normal ankles it is recommended that the instability of the injured ankle be compared with the movement of the normal ankle (Cedell 1975, Rubin & Witten 1960). This was also practised in the present study.

Table 2 *The clinical diagnosis in relation to the radiological diagnosis in 62 outpatients with suspected lateral ligament lesion of the ankle*
Talar tilt investigation

Radiological diagnosis		Normal		Ligament lesion		Total	
	Clinical diagnosis	SS	LL	SS	LL	SS	LL
Normal	SS	14		3		17	
	LL		8		6		14
Ligament lesion	SS	3				3	
	LL		19		9		28
Total	SS	17		3		20	
	LL		27		15		42

SS simple sprain

LL ligament lesion

Table 3 *The operative diagnosis related to the radiological diagnosis in 86 patients operated on because of suspected lesion of the lateral ligaments of the ankle (In one patient with positive ADS no lesion was found at operation)*
Talar tilt investigation

Radiological diagnosis	Normal		Ligament lesion		Total		
	Operative diagnosis	LTF	LTF + LCF	LTF	LTF + LCF	LTF	LTF + LCF
Normal	LTF	3		4		7	
	LTF + LCF				15		15
Ligament lesion	LTF	10		3		13	
	LTF + LCF		12		38		50
Total	LTF	13		7		20	
	LTF + LCF		12		53		65

LTF lesion of the anterior talofibular ligament

LCF lesion of the calcaneofibular ligament

Table 4 *Monthly distribution of the results of the talar tilt (TT) and the anterior drawer sign (ADS) examinations in 86 patients operated on because of suspected lesion of the lateral ligaments of the ankle*

	Ligament lesion disclosed by			Positive investigation		Falsely positive investigation		ADS + TT negative	Total
	TT	ADS	Both	TT	ADS	TT	ADS		
October	2	3	11	13	14				16
November	5	8	11	16	19			1	25
December	2	7	9	11	16				18
January	4	3	7	11	10				14
February	6	1	3	9	4		1	2	13
Total	19	22	41	60	63		1	3	86

both in the TT and the ADS examinations A source of error in this comparison is a previous severe trauma on the now unaffected side None of the patients in the present series had been exposed to such a trauma

Ligament rupture was diagnosed if the TT on the injured side exceeded that on the normal side by 3 mm or more This limit corresponds to a difference of 6° as recommended by Freeman (1965)

Various methods have been recommended for measurement of the anterior instability by ADS (Castaing & Delplace 1972, Lindstrand & Mortensson 1976, Larsen 1976) In the present series ligament rupture was diagnosed by ADS if there was a difference in displacement of 2 mm or more between the two sides The limit of 2 mm had been determined in a pilot investigation performed on patients with surgically verified ligament lesion

The fixed points chosen give the methods a great advantage over those used by other authors Both points represent midline structures, which means that both ankles can be examined from the same side Another advantage of the method presented is that the double exposure of the film makes it possible to measure the displacement on each side on the one film

The figures quoted regarding the out-department group should be taken with a certain reservation, because of the absence of verification of the ligament ruptures However, if the clinical diagnoses are accepted as correct about 50 per cent of the ligament ruptures were disclosed only by the ADS This figure is very high, compared with the 25 per cent in this group with ruptures which were diagnosed only by the TT The explanation for this is probably a certain scepticism on the part of the clinicians as to the value of the ADS, so that patients with positive signs of ligament rupture disclosed only by the ADS were more often sent to the outpatient department than patients with positive signs of ligament rupture only by the TT

One or other of the methods failed in about 25 per cent of the surgically verified cases

but the methods were complementary so that if one was negative the other was usually positive In only 5 per cent of the surgically verified cases were both methods negative at the same time In addition both methods were negative in 20 per cent of the ligament lesions in the outpatient department group The number of falsely negative examinations may possibly be reduced in both investigations by using local anaesthesia of the injured ligaments to avoid a pain-determined fixation of the ankle (Lindstrand & Mortensson 1976) Moreover it is possible that an increased load can reduce the number of falsely negative results with the ADS

In the first period during which both methods were performed with meticulous care by one investigator, the efficiency of both methods was the same In the second period during which both the TT and the ADS examinations were used routinely the ADS being performed by X-ray technicians the efficiency of the ADS showed a definite decline The reason for this most probably is that it is of crucial importance that the patient is completely relaxed when the ADS examination is performed This requires some time, which may be difficult for the technicians to accept, especially in a stressful situation To make the ADS investigation just as efficient as the TT it is recommended that the examination be performed by doctors Otherwise very careful instruction of the technicians with constant checks giving special emphasis to the importance of a completely relaxed patient is necessary

The interpretation of the X-ray films was a little more difficult in the ADS investigation than in the TT However, with some experience this gave no special problems and in the reappraisal of all the exposures only a few false measurements were disclosed

The ADS has some very great advantages over the TT Firstly, the ADS is definitely less painful for the patient and secondly the ADS is safer with regard to scattered radiation, because no member of the staff has to stay in the examination room during the exposure

The anterior talofibular ligament is the most important stabilizing ligament of the ankle (Cedell 1975). Moreover, the anterior talofibular ligament is damaged in nearly 90 per cent of all ligament injuries in the ankle — in 66.5 per cent alone and in 20 per cent in combination with other ligament injuries (Broström 1966).

In an experimental study, Castaing & Delplace (1972) found that cutting of the anterior talofibular ligament was followed only by anterior instability of the ankle joint (ADS). TT occurred only when the calcaneofibular ligament was also cut. By the two methods, it should therefore be possible to differentiate between lesions of the anterior talofibular ligament and combined lesions of the anterior talofibular and the calcaneofibular ligaments.

In the series presented here, isolated lesion of the anterior talofibular ligament was found in 25 per cent of the operated cases. When only ADS was positive, the lesion was more often localized to the anterior talofibular ligament. Localized lesion of the anterior talofibular ligament was, however, in some cases disclosed only by TT, and lesion of the calcaneofibular ligament was found in some cases in spite of the negative TT.

Conclusions

Ligament lesions which are not disclosed by the TT examination may be diagnosed by the ADS.

The ADS cannot replace the TT examination, or *vice versa*. The two methods are complementary.

It is not possible to differentiate between isolated lesion of the anterior talofibular ligament and a combined lesion of the anterior talofibular and the calcaneofibular ligament by the two methods.

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LATERAL INSTABILITY OF THE ANKLE TREATED BY A MODIFIED EVANS PROCEDURE

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A technically simple tenodesis of the peroneus brevis tendon has been applied in the treatment of 42 patients with lateral instability of the ankle. 33 patients have been examined 2-10 years after the operation and 91% cent showed excellent or good results. It is concluded that this procedure gives good stability in the varus as well as the antero-posterior direction and is therefore comparable to the technically more difficult Watson-Jones procedure.

Key words: lateral instability of the ankle, tenodesis, peroneus brevis tendon.

Accepted 21.1.78

Posttraumatic lateral instability of the ankle is a condition with well-defined clinical symptoms. An inversion trauma sometimes leads to recurrent sprains, a feeling of instability, and periodic pain and swelling below and in front of the lateral malleolus. Several operative procedures to stabilize the ankle have been presented during the last 40 years. In many of these the peroneus brevis tendon has been used as a substitute for the ruptured lateral ligaments. Brostrom (1966) considered a direct suture of the torn ligaments possible several years after the primary trauma. In many cases however some kind of ligamentous reconstruction is necessary. Hitherto the Watson-Jones repair appears to be the most widely used procedure (Watson-Jones 1952, Anderson & Le Cocq 1954, Lemberger & Kramer 1971, Gillespie & Boucher 1971).

PATIENTS AND METHODS

Between 1964 and 1974, 42 patients with lateral instability of the ankle were operated on in the orthopaedic department of Borås Central Hospital. The operative procedure used was a slight modification of those described by Nilsson (1955) and Evans (1953). A slightly curved incision was made over the peroneal tendons down to the tip of the lateral malleolus. The tendons are isolated at the level of the proximal retinaculum, which can be carefully preserved. The peroneus brevis must be sectioned just below the musculotendinous junction. The proximal end is sutured to the peroneus longus, while the distal end is directed down through the proximal retinaculum. A channel of about 7 mm diameter is then drilled in the bone of the lateral malleolus from the tip directed proximally and dorsally. The tendon is driven through the channel. The patient is placed in a below-knee walking cast for 6 weeks, followed by mobilization with full weight-bearing.

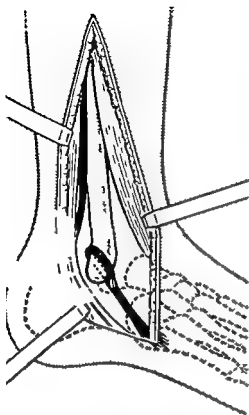


Figure 1 Schematic illustration of the operation for suturing of the peroneus brevis tendon

All the case records were almost identical. A very heavy sprain was followed by a feeling of instability, weakness of the ankle, periodic pain and recurrent sprains. The condition was in all cases associated with marked physical disability in connection with sporting activities such as tennis, minton, golf and cross-country running. Because of the large normal variations in talar tilt (Lynn et al 1968) the operative indication was based more on the clinical status than on the X-examination.

The series consisted of 21 male and 12 female patients. At the time the investigation was carried out one of the 12 patients had died and eight patients were not available for other reasons (mainly because of the great turnover of inhabitants in this part of the country). The age at operation averaged 33 years (range 15–63 years). The time from primary trauma and operation averaged 6 years (range 1–27 years) and follow-up time 5 years (range 2–10 years).

At follow-up the patients outlined their subjective condition by answering a special

questionnaire. All the patients were examined clinically with respect to 1) Ankle joint mobility 2) Stability (varus instability and/or "drawer" symptom) 3) Peroneal function and circumference of the calf 4) X-ray (AP sagittal and forced supination).

RESULTS

No operative complications were recorded. Table 1 presents the subjective results. In the group "improved" there were slight complaints such as swelling at the lateral malleolus (11 cases), sporadic distortions (6 cases) and periodical pain (5 cases).

The three patients in the group "not improved" considered their ankle joints to be just as unstable as before operation. One of these demonstrated a completely normal status clinically and on X-ray. The ability to perform sports activities is presented in Table 2. Preoperatively no patient was able to take part in any form of sporting activity.

Table 1 Subjective results in 33 operated cases

Result	No. of cases	Per cent
No complaints	19	58
Improved	11	33
Not improved	3	9
Total	33	100

Table 2 Postoperative physical ability

Sporting activity	No. of patients	Per cent
Competitive athlete	6	18
Occasional sport	23	70
No sport at all	4	12
Total	33	100

At the clinical examination supination was reduced by less than 10° in 10 patients. In five cases a very slight "anterior drawer sign" could be demonstrated, while no patients revealed varus instability. Moderate swelling at the lateral malleolus was found in five cases. Peroneal strength compared to the non-operated side was normal, and there was no atrophy of the calf muscles.

Slight to moderate osteoarthritis was recorded in two patients and advanced osteoarthritis in one. In two of these three cases, however, the X-ray picture was completely unchanged in comparison with the pictures taken preoperatively.

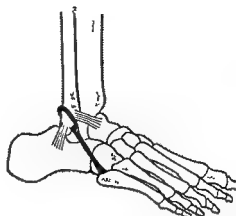


Figure 2 Position of the transplant between the two relevant ligaments

DISCUSSION

Lateral instability of the ankle is a disabling condition, which reduces the mobility of the patient, especially on uneven ground. In elderly patients relief of symptoms may be obtained by nonoperative measures, such as peroneal strengthening exercises. The majority of younger and middle-aged patients demand surgical treatment, in order to improve their physical performance. In addition to the technique of direct suturing (Brostrom 1966) good results have been presented after use of the Watson-Jones repair (Watson-Jones 1952, Anderson & Le Cocq 1954, Lemberger & Kramer 1971, Gillespie & Boucher 1971). This repair includes a transfer of the peroneus brevis tendon through the talus, which makes the operation technically more difficult than the modified Evans procedure we have used. The anterior fibulo-talar ligament is considered to be the most important of the lateral ligaments, from the point of view of stability (Leonard 1949, Brostrom 1966, Laurin et al 1968). The position of the transplant in the modified Evans procedure described here seems to substitute for the function of this ligament as well as that of the fibulo-calcaneal ligament (Figure 2). The procedure was performed after sectioning of the two ligaments in a cadaveric specimen and a good

stabilizing effect in the antero-posterior as well as varus direction was noted. The modified Evans procedure is a simple method of treating lateral instability of the ankle. The stabilizing effect seems very good. Also the subjective results are very gratifying.

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CENTRIPETAL COMPRESSION TRIPLE ARTHRODESIS

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Forty-nine compression triple arthrodeses were performed in 45 patients

cases, and within 8 weeks in the remaining 63 per cent. Non-union was completely avoided and the period until fusion reduced to almost half that expected after conventional operations. The compression also ensured maintenance of the correction of deformity initially obtained.

Key words: foot, arthrodesis, triple arthrodesis by centripetal compression

Accepted 29.1.78

Since Ryerson described triple arthrodesis of the foot in 1923 the methods used for internal fixation of the tarsal bones have been either transfixation by Kirschner wires (Caldwell 1949) or staples (Burns 1946). The present paper presents a modified external compression technique which ensures a more rigid fixation of the tarsal joints. The use of compression shortens the healing time and prevents the occurrence of non-union.

PATIENTS AND METHODS

Forty-nine operations were performed in 45 patients (Table 1), 21 on the right side, 20 on the left and 4 bilaterally.

The age of the patients ranged from 12 to 35 years with an average of 15.5 years. Thirty-eight patients were males, seven were females.

All patients were followed up clinically and roentgenologically for 1-6 years after the operation (average 4 years).

The fixation device is illustrated in Figures 1-3. It consists of

(1) Three Steinmann pins

- (2) Two large rings each with three blocks with three transfixion screws in the end
- (3) Six small transfixion rings

Table 1 Indications for centripetal compression triple arthrodesis

	Number of patients
Spasmodic flat foot	23*
Rigid painful static flat foot	3
Fractures of the calcaneus with involvement of the subtalar and calcaneocuboid joints	4
Poliomyelitis with deformed unstable feet	12
Pes cavus associated with spina bifida occulta	1
Neglected congenital talipes equinovarus	1
Chronic tarsal tuberculosis	1

Total

* Four of these patients had bilateral

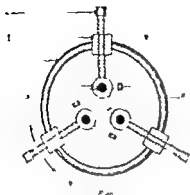


Figure 1 Diagram of the compression apparatus. The movable block (1). The compression screw (2) whose smooth tip fits into a small hole in the small transfixion ring (4), which is anchored to the Steinmann pin (5) using a small screw (6). The large ring (3).

Each of the two large rings, 11 cm in diameter, has three movable blocks. Each block measures $1 \times 2 \times 2$ cm with a central core 8 mm in diameter. This permits free mobility around the ring and its pins. The block may be fixed at any desired point in the ring and in any desired plane by means of a screw. Passing centrally through each block is a compression screw 45 mm in length. To the end of this screw a small transfixion ring is attached. Through the transfixion ring the Steinmann pin is passed into the tarsal bones. By rotating the compression screw in the block its tip exerts pressure on the pins thus producing a centripetal compression of the resection surfaces.

The operation is performed through a medial incision centred over the talonavicular joint and an appropriate wedge is excised according to the deformity present. Following this a lateral incision starting 1 inch below the lateral malleolus and ending over the base of the fifth metatarsal is made. The peroneal tendons are retracted and the extensor digitorum brevis dissected distally and medially. Another wedge is excised from the calcaneocuboid joint. This facilitates posterior displacement of the forefoot. The talocalcaneal joint is thereafter resected with removal of an appropriate wedge in order to correct any heel deformity. The first Steinmann pin is introduced laterally and downwards through the navicular and cuboid bones. The second is placed horizontally across the talar neck. The third pin is placed horizontally in the postero-inferior part of the os calcis.

The small transfixion rings are fixed to each end of the Steinmann pins a few centimetres away



Figure 2 Postoperative X-ray showing the centripetal compression device applied to the foot

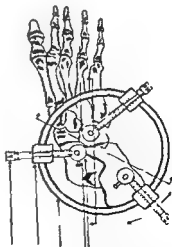


Figure 3 Diagram of the centripetal compression apparatus applied to the foot. Note that one large ring is shown and that the three blocks can be moved to any part of the

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Pes cavus associated with spina bifida occulta	
Neglected congenital talipes equinovarus	
Chronic tarsal tuberculosis	
Total	4
* Four of these patients had bilateral operations	

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CALCANEAL CYSTS

A Radiological and Anatomico-Pathological Study

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A radiological and anatomico-pathological study of 17 cases of calcaneal

hemorrhages, (2) newly formed bone – similar to that observed in some cysts of the humerus and femur – applied in preexisting trabeculae which forms a bony wall explaining the typical radiological picture

These uncommon cysts may be the evolution of purely local hemorrhage in the trigonum calcis

Key words: bone cysts, calcaneum, intra-osseous hemorrhage, cholesterol granuloma

Accepted 1.x.77

Calcaneal cysts are quite uncommon and since Smith's observation (1930) only about 100 cases have been reported in the literature. Most of these were asymptomatic.

Seventeen surgically removed calcaneal cysts were studied and this report deals with their radiological and pathological appearances.

MATERIAL AND METHODS

Each of the 17 subjects (15 men and 2 women) with ages ranging between 10 and 37 years (average 23 years, s.d. 5.35) had a unilateral cyst of the anterior calcaneus. Five were situated on the right and seven on the left. In five cases the side was not mentioned.

Four patients complained of moderate heel pain. In the remaining cases the cyst was an accidental radiological finding (often after a minor trauma). A surgical curettage was performed in all cases.

* Aspirant du Fonds National de la Recherche Scientifique Belge.

The material, fixed in 10 per cent formalin, was paraffin embedded, and sections were stained with hematoxylin-eosin (HE), van Gieson, Gomori silver impregnation and Pearl's stain. In one case lipids were looked for with the Oil red O stain. gelatin embedded tissue

OBSERVATIONS

Radiology

The radiological picture in each case was that of an anterior calcaneal lacuna with an almost trapezoidal form, sometimes circumscribed by a thin border of condensed bone (Figure 1). On two occasions, axial views revealed a lateral position.

Pathology

Histologically, the material was made up essentially of a wall of fibrous scar tissue (Figure 2) containing varying quantities of hemorrhage (Figure 3a). In seven cases cholesterol was noted (directly with Oil red O or indirectly with HE or van Gieson) within histiocytes or in the form of crystals provoking a foreign body giant cell reaction.

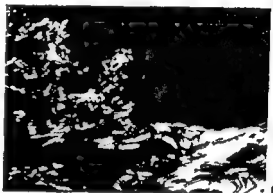


Figure 1 X ray of anterior calcaneal cyst (lateral view - 0.9x) (a) Cyst surrounded by a well defined bony border (T 12634/67 - 22 year old male) (b) Cyst with a 'leafy' wall (T 5093/66 - 7 year old male)

Figure 2 Histological appearance of the cyst wall (T 4081/76 - HE stain - 6x) Lower right compact lamellated bone To the left mostly lamellated remodelled bone (and in places woven bone) Superior border of this bony wall is covered by a layer of connective tissue which lines the cyst cavity (a) Normal light (b) Polarized light

Figure 3b). In three cases the fibrous material intermingled with newly formed coarse trabecular osteoid tissue. This was either typically "reparative" (Figure 4) or composed of flakes with peculiar woven appearance (Figure 5). In two of cases the fibrous osteoid tissue was to partially remodelled preexisting (Figures 2 and 4). The 14 remaining non specific osteogenic and fibrous which could be due to variations in the the excised material. Infectious or tumoral lesions as well as bone in were excluded on histological examination.

The average age in both series is comparable [20 years in the literature but with a greater variation ranging from 4 years (Kingsbery 1957) to 65 years (Denis 1965)]. There is definitely a male predominance which was also present in our series. The cysts may be seen on either side with about equal frequency but bilateral cysts are rarely observed (Bachicco & Leonessa 1968 Christman & Kopell 1961 Kingsbery 1957 Lentini 1967).

A history of trauma is found in approximately one out of ten cases. Only two reports from the literature mentioned the presence of fractured cysts (Aegerter & Kirkpatrick 1968 Malcap & Turrini 1963).

Our findings were compared to those described in the literature and from these comparisons a number of interesting points have arisen.



Figure 3 Detail of connective tissue portion of cyst wall (T 12634/67) (a) Fibrous tissue & clefts of cholesterol crystals (half) near adipose tissue & hemosiderin deposits (lower part) Pearl's iron stain (no counts of the nuclei) - 35x (b) Granulation tissue with clefts of cholesterol crystals and giant cells (right) joined to fibrous tissue (left) hematoxylin & eosin 8x

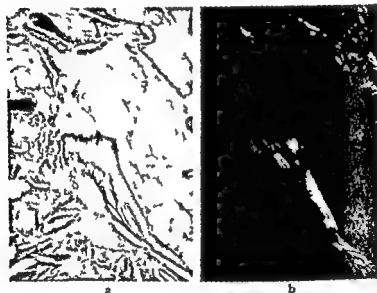


Figure 4 Detail of connective tissue external area of cyst (T 12634/67 - HE - 13 5x) (a) left granulation tissue with clefts of cholesterol crystals. In center preexisting lamellated trabeculae. Top newly formed woven bone (a) normal light (b) polarized light

Pain is only present in one fourth of the cases and thus correlates well with our series. Frequently the pain is accentuated by pressure and especially when walking. Swelling which has been noted by various authors was not noted in the present series. Radiologically one case was considered as having healed spontaneously 21 years after diagnosis (Smith & Smith 1974).

In the literature there are about 40 histologically proven cases described including one in a specimen from an amputated limb (Calcagni 1963). All of these cases showed fibrosis frequently accompanied by hemosiderin deposits, foam cells,

cholesterol crystals and a hemorrhagic exudate in the cavity (Aegerter & Kerk 1968, Ayres & Cameron 1957, Bachmann & Leonessa 1968, Palma & Venturini 1969).

Differential diagnosis

Evidence accumulated from the literature and from our own observations is sufficient for the recognition of an entity to be referred to as the anterior calcaneal cyst, based on the characteristic radiological picture associated with the finding of cystic degeneration. Osteogenic scar tissue, hemosiderin deposits as well as cholesterol deposits seem to be the main histological characteristics.

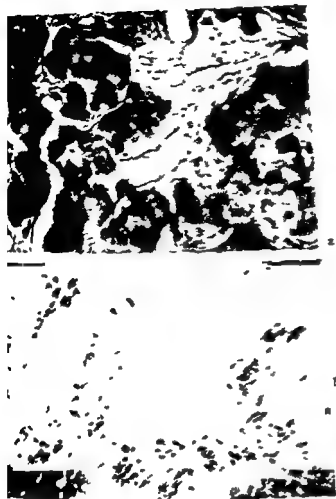


Figure 5. Osteoid flakes with spiral woven appearance. Dilat cartilages in the intervertebral spaces (T 57/274 - HE - 47). (a) Normal light. (b) Polarized light.

These cysts should be differentiated from other calcaneal cysts and especially those in the posterior superior calcaneus which have been documented twice in the literature (Barbieri 1969, Christman & Kopell 1961). They should obviously be differentiated from erosive conditions of the calcaneus described in relation to xanthomatosis of the Achilles tendon (Sneider 1963).

Furthermore, they should not be confused with infectious and tumoral lesions which have different radiological appearances and can be found in any area of the calcaneus (Bonnet et al. 1968, Demis 1965). In fact, all infectious and tumoral (benign or malignant) lesions that may affect the skeleton have been

observed in this bone.

A calcaneal cyst related to an arthropathy such as described in a case of rheumatoid arthritis (Copeman 1955) is exceptional and must be integrated into the overall radiological findings. A radiological and anatomic study of a calcaneus, modified by old Sudeck's dystrophy, has shown that it does not resemble a case of calcaneal cyst (Lager & Van Linthoudt, in press).

It is also necessary to eliminate all of those cases presenting similar radiological picture which do not have the anatomico-pathological criteria of a cyst, such as bone lipomas (Appenzeller & Weitzner 1974, Pousa & Holmstrom 1976).



Figure 6 Normal calcaneus (A 609/71 - 63 year old male - right side - 0.7x) (a) X-ray of the lateral half (b) Macerated specimen corresponding to the preceding X-ray (c) Medial parasagittal section (embedded in celloidin - HE stain) Bone marrow consists mostly of fatty tissue particularly in the trigonum calcis

Pathogenesis and characteristics

From our observations three main characteristics explaining the pathogenesis of these cysts can be formulated

(1) These cysts, because of their location, could be considered as a normal anatomical pattern. It is the trabecular architecture of the bone that forms at this level the



Figure 7 Arterial supply of normal calcaneus (T 1369/77 - 60 year old male - left side - x0.7). Lateral parasagittal section. Arterial blood vessels are injected with Indian ink. Transparency of bone obtained by the Spalteholz technique

delimited above by an arch of trabeculae whose structure is influenced by the stress of body weight and below by concave trabeculae situated against the corticis which are affected by traction. Photo-elastic studies on models (Mülch 1940, cited in Lentini 1967) have shown that this zone remains free from the mechanical strains affecting the neighboring areas. The interior of the trigonum contains fatty bone marrow, thus under normal conditions an anterior radiolucent area appears on the X-ray of a calcaneus and this may at times be accentuated, causing the pseudo-cystic images described by Sarr (1951) in 71 per cent of his series (Figure 6). These areas can be differentiated from true cysts by the fact that they are triangular in form and do not have a limiting bony wall.

(2) The histology showed that the bony wall of the cysts developed by an osteogenic metaplasia against the preexisting lamellar bone trabeculae and on the exterior surface of thin scarred connective tissue containing deposits of hemosiderin and cholesterol. It is well documented that this type of scarred connective tissue is due to the organization of hemorrhages such as that observed in the case of cholesterol granulomas of the ear or in experimental models (Dota et al. 1954; 1959; Main et al. 1970).

We consider these cysts of the calcaneus to be the result of

organizing hemorrhages in the region of the trigonum calcis. This could be related to the rather rich vascularization of this area (Chanzy et al. 1973, Crock 1967) (Figure 7). It suggests a pathogenesis already proposed by Pommer for bone cysts, one which was also discussed for the formation of humeral and femoral cysts (Jaffé & Lichtenstein 1942, Lang 1954, Pommer 1919). In fact, we have observed that the newly formed bone in the wall of humeral or femoral cysts — which also develop under an arch of trabeculae — may be represented by the same peculiar woven osteoid material seen in Figure 5. Their great rarity (even after trauma) and the lack of any relation with hemorrhagic conditions [the hemophilic cysts of the calcaneus have a different appearance (Bonnet et al. 1968, Giambelli & Lanzetta 1964)] implies that an exceptional combination of various mechanical and vascular factors must be necessary for their formation. Among other things there may even be a relationship with the venous pressure of the lower leg. When this is increased, the pressure within the calcaneus also increases (Arnoldi & Linderholm 1971).

ACKNOWLEDGMENTS

We would like to express our gratitude to Prof B de Montmollin (Neuchâtel), Prof H G Wilfert (Frankfurt-am-Main), Dr J Barambon (Geneva), Dr P Corboud (Fribourg), Dr M Duc (Sion), Dr R Fallier (Moutier), Dr E Jeannot (Lausanne), Dr A Megevan (Geneva) and Dr J-Ch. Mottuoni (Geneva) for supplying us with the clinical and radiological findings of the cases that we studied.

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DEGENERATIVE CHANGES IN THE FIRST METATARSO-PHALANGEAL JOINT OF BALLET DANCERS

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In 20 female performers of classical ballet the range of dorsiflexion of the big toe was found to be significantly decreased. However, in only one case was the decrease sufficiently great to interfere with the dancer's ability to perform. In spite of the severe stress put on the first metatarso-phalangeal joint in dancers the resulting degenerative changes were found to be minor and in most instances without clinical consequences. The results indicate that professional ballet, contrary to what is generally believed, rarely has harmful effects on the first metatarso-phalangeal joint.

Key words: ballet, dancing, hallux rigidus

Accepted 24/78

Degenerative changes, mostly osteophytes, particularly in the talar joint have been demonstrated in female performers of classical ballet (Brodelius 1961, Miller et al 1974). Dunn (1965) pointed out the importance of protection of the big toe and the metatarso-phalangeal joints in dancers, particularly female dancers who dance with their feet in the "sur la pointe" position. Dancing with a rigid first metatarso-phalangeal joint puts considerable strain on the foot and ankle and tends to create a "sickling" position with supination of the foot which in turn causes pain and spoils the dancing posture. Similar observations have been presented by Miller et al. (1974) indicating that hallux valgus, bunions and callosities are common in the feet of female dancers. So far, no reliable method has been

devised to protect the first metatarso-phalangeal joint in female dancers, nor has any series of successful surgical procedures for hallux rigidus in female performers of classical ballet been presented.

The objective of this study was to measure the range of motion in the first metatarso-phalangeal joints in female ballet dancers and to make a comparison with a control population of non-dancers.

MATERIAL AND METHOD

Included in the study were 20 female ballet dancers, members of the ballet company of the Malmö City Theatre, and 34 approximately age-matched controls, mainly hospital employees without any history of injury or disease of the forefoot. The age of the dancers was 28 ± 7 . They were all professional and had been dancing since early childhood. The range of motion was tested in the same way and by the same investigator in all the subjects using a square rule (Figure 1). In the ballet dancers additional measurements were

Financial support was obtained from the Swedish Medical Research Council (project No. B 77-17X-2737-09B), Greta and Johan Kock's Foundation and Alfred Österlund's Foundation.

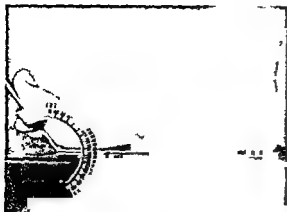


Figure 1 Measurement of dorsiflexion of the first metatarsophalangeal joint. The maximum dorsiflexion is measured with the patient standing and the ankle joint in the neutral position.

taken immediately after a performance. The average of left and right was used since there was no systematic left-right difference.

RESULTS

There was no significant change in the range of motion with age either in the dancers or in the controls (Figure 2). There was, however, a difference in the range of motion between the two groups which only amounted to a few degrees; this difference was significant ($0.02 > P > 0.01$). In fact, only one dancer

H, aged 23) deviated significantly from the rest of the cases and this girl also had

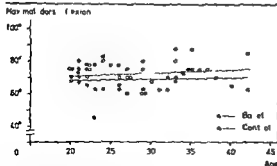


Figure 2 The relationship of age and big toe dorsiflexion in female dancers and age-matched controls.



Figure 3 The foot of dancer (K.H.) in "pointe" position. Note the perfect arch of foot and toes which supports the entire body weight.

clinical symptoms associated with her dancing. There was no difference in the range of motion in ballet dancers before and immediately after a performance. Radiograms were obtained of the six female dancers who had the most restricted range of motion. Of these six, three were found to have small osteophytes on the margins of the metatarsal head, however, the radiological signs were not associated with clinical symptoms except in the one girl mentioned above with a range of motion decreased by about 40 per cent.

DISCUSSION

There is little doubt that in female ballet dancers a tremendous load is taken by the first metatarsophalangeal joint in the "pointe" position and that this joint is

subjected to repeated trauma over the years (Figure 3). Also, the appearance of the feet of these performers with large multiple callosities supports the concept that the toes and particularly the big toe are weight-structures. Under these conditions it is surprising that so few and so moderate changes were found. It should be noted that the radiological changes mentioned above were only osteophytes and not osteoarthritis in its true sense. In conclusion, ballet dancing may not be as harmful to the

forefoot of young women as has been proposed in the past.

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ANNOUNCEMENT

THIRD STRATHCLYDE SEMINAR

Rehabilitation of the Disabled – Clinical and Biomechanical Aspects.

August 8–11, 1978 in Wolfson Centre, Strathclyde.

The Seminar will be attended by an international body of specialists.

For information contact Professor R.M. Kenedi, University of Strathclyde, Bio-engineering Unit, 106 Rottenrow, Glasgow G4 0NW, Scotland.

SIMULTANEOUS TRAUMATIC POSTERIOR DISLOCATION OF BOTH HIPs

A Case Report

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Simultaneous traumatic posterior dislocation of both hips, uncomplicated by fracture, is an exceptionally rare entity. The authors could not find any record of a similar case in the world medical literature up till now, and are therefore reporting this case with special consideration of the mechanism of injury and the management.

Key words: dislocation of hips, bilateral posterior

Accepted 16.11.78

CASE REPORT

A 56-year-old male of thin build was travelling seated in the rear seat of a car. He was rather tightly placed between other passengers. When the car had a head-on collision with another vehicle he was pushed forward with great force jamming his knees against the back of the front seat. Following the incident the patient was brought to the Nemazee Hospital with complaints of severe pain in both hips and inability to move the hips and straighten the legs. He was found to be in

shock with both inferior extremities in flexion adduction and internal rotation so that the legs were almost crossing each other. All active and passive movements of both hips were absent. Both the femoral heads were palpable in the gluteal areas. There were no signs of other lesions.

X-rays demonstrated posterior dislocation of both hips (Figure 1). The hips were reduced under general anaesthesia with the patient lying supine on the floor. X-rays confirmed that the reduction was successful. At the most recent follow-up 8 months after the injury he remained symptom-free with normal radiological findings.

DISCUSSION

Most posterior dislocations of the hips are due to dashboard injury to the flexed adducted leg of the front-seat passenger (Apley 1976). Our patient was unusual in that he was a rear-seat passenger. He was seated with both legs flexed and adducted at the hips when a forceful impact of the knees against the back of the front seats led to simultaneous dislocation of both hips.

Bilateral dislocation of the hips associated with fractures of either femur or acetabulum has already been described by Lydén &



Figure 1 X-ray showing posterior dislocation of both hips

Hartman (1971) and Ingram & Turner (1954), but an uncomplicated case such as this has not been recorded so far

Lyddon, D W, Jr & Hartman, J T (1971) Traumatic dislocation of hips with ipsilateral femoral fractures. A case report. *J Bone Jt Surg* 53 A 1012-1016

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EFFECT OF INDOMETHACIN ON COLLAGEN METABOLISM OF RAT FRACTURE CALLUS *IN VITRO*

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The collagen metabolism of callus tissue from closed non-immobilized rat femoral fractures was studied *in vitro* after *in vivo* treatment with indomethacin 2 mg/kg/day for 6, 9 and 12 days after fracture. Total hydroxyproline synthesis and incorporation of hydroxyproline into collagen were found to be significantly increased after indomethacin treatment whereas no significant difference was found regarding collagen resorption. The results suggest that the recently demonstrated inhibition of fracture healing by indomethacin is not brought about by an inhibition of collagen synthesis.

Key words: anti-inflammatory agents, bone, callus, fractures, indomethacin, rats

Accepted 6.11.78

Non-steroidal antiphlogistics are used for the treatment of a wide range of diseases. They are also used to reduce the acute inflammation following trauma. Most publications studying the effect of these drugs on fracture healing conclude that such treatments do not affect the healing process (Eschberger 1973, Nordenram & Bang 1970).

However, three recent publications report delayed fracture healing in experimental models after indomethacin treatment (Huusko et al 1975, Sudmann 1975, Rø et al 1976). The effect of antiphlogistic drugs on collagen outside bone has been studied by many authors and results are divergent (Aalto & Kulonen 1972, Farnsey et al 1975, Fukuhara & Tsurufuji 1969, Kulonen & Potila 1975, Lee 1968, Lee & Tong 1970, Morton & Malone 1972, Winter 1965). The divergent results may depend on the different doses administered (Aalto & Kulonen 1972, Kulonen & Potila 1975).

*Dr Rø died in April 1976.

The present study was planned to investigate the effect of indomethacin administered *in vivo* on the *in vitro* metabolism of collagen of fracture callus tissue from rats. In the system used both collagen synthesis and resorption can be studied separately (Flanagan & Nichols 1969, Langeland 1975).

MATERIAL AND METHODS

Forty-two male rats of the Wistar/Møllegaard strain were divided into two matched groups. One group received indomethacin 0.4 mg (Indocid suspension 0.4 mg/ml, Merck Sharp & Dohme, Haarlem, The Netherlands) by stomach tube once daily. The resultant dose of indomethacin was about 2 mg/kg/day. The other group serving as a control was given equivalent amounts of the vehicle. The first doses were given immediately after having fractured the animals' left femur (Rø et al 1976).

The treatment was continued until sacrifice of the animal. The pair matched animals were divided into three series.

- I Twelve rats sacrificed 6 days after fracture and start of treatment Initial weight 194.9 ± 4.7 g At sacrifice the indomethacin treated animals weighed 222.8 ± 8.1 g and their controls 214.0 ± 14.4 g The difference was not significant
- II Twelve rats sacrificed 9 days after fracture and start of treatment Initial weight 194.9 ± 4.7 g At sacrifice the indomethacin treated animals weighed 234.3 ± 7.7 g and their controls 234.3 ± 8.9 g The difference was not significant
- III Eighteen rats sacrificed 12 days after fracture and start of treatment Initial weight 197.4 ± 2.8 g At sacrifice the indomethacin treated animals weighed 245.7 ± 8.5 g and their paired controls 251.1 ± 9.3 g The difference was not significant

The animals of series I and II, treated for 6 and 9 days, were, at the end of the experiment, anaesthetized with ether Blood was collected from the vena cava for indomethacin analysis and after that the animal was bled to death

The animals of series III, treated for 12 days, were, at end of the experiment, killed by a blow to the neck and decapitation

In all animals the left hind limb with the fractured femur was exarticulated at the hip joint and immediately cooled to 0° – 2° C While still in the cold (0° – 2° C) the callus tissue was carefully dissected free

The 6- and 9-day-old callus was cut into 0.5 mm slices in a microtome while the 12-day-old callus was cut into pieces of 1–2 mm³ by hand (Flanagan & Nichols 1969) The subsequent procedure, including the incubation, was as previously described (Borle & Nichols 1960, Flanagan & Nichols 1969, Langeland 1975) To the media were added proline 15 mM and Proline (U)-¹⁴C (SA 290 mCi/mmol, from the Radiochemical Centre, Amersham)

The amount of hydroxyproline was determined by the direct acid method of Firschein (Firschein & Shill 1966, Firschein 1969) To determine specific activity of the hydroxyproline, the amount of hydrolysate was evaporated in a rotary evaporator The residue was dissolved in 250 μ l H₂O and hydroxyproline was isolated using a 50 W-x8 200–400 mesh, 0.8 x 20 cm column described by Firschein (1969) The hydroxyproline fraction of the eluate was once again evaporated and put on a TLC-plate (TLC Woclin 20 x 20 cm, pre-coated silica gel 60 F₂₅₄)

The portion of the eluate containing the hydroxyproline (3 mm stripe) was eluted in 2 ml H₂O and centrifuged for 5 minutes at 5000 g Of the eluate 150 μ l was used for hydroxyproline analysis according to the direct acid method of Firschein (Firschein & Shill 1966) while 1500 μ l was added in 20 ml Unisol (Koch Light) and counted in a Nuclear-Chicago Mark II Liquid Scintillation counter Sp activity was calculated based on these results Media from 1–3 hours and 4–6 hours were pooled, treated and analysed as previously described (Juva & Prockop 1966, Langeland 1975)

Calculations were done as described by Flanagan & Nichols (1969) and the statistical significance of differences was tested by the Wilcoxon test (Wilcoxon 1947) or the Wilcoxon Van Elteren test for grouped data (Hayland & Walloe 1975)

RESULTS

The wet weight of the callus tumour is given in Figure 1 At 6 days there was no difference between indomethacin treated and untreated animals in this respect However, comparing the grouped data of 6, 9 and 12 days the indomethacin treated animals had a higher weight of callus tumour than their controls The same tendency can be seen when studying the total collagen content of callus tumour (Table 1) although these differences are insignificant Both the total hydroxyproline synthesis (Figure 2) and the deposition of hydroxyproline into collagen of callus tissue (Figure 3) are significantly higher in the indomethacin treated animals Studying the deposition of hydroxyproline into collagen this parameter is higher in the treated

Incubation in 95 per cent O₂/5 per cent CO₂ in a New Brunswick Incubator G 24 (New Brunswick, New Jersey USA) at 100 oscillations/min and 37.5° C for 6 hours 4 ml of medium was added to each flask

The decanted medium was immediately chilled to 0° – 2° C, then centrifuged at 5000 g for 10 minutes and hydrolyzed in equal amounts of 12 N HCL in sealed ampoules at 125° C for 4 hours

The callus tissue was, immediately after incubation, chilled to 0° – 2° C, washed in two changes of chilled Krebs-Ringer buffer and hydrolyzed in 6 N HCL (2 ml/100 g wet weight) in sealed ampoules at 125° C for 18 hours

Analysis The tissue hydrolysates were treated with humin precipitate (Prockop & Udenfriend 1960), centrifuged and the volume was adjusted

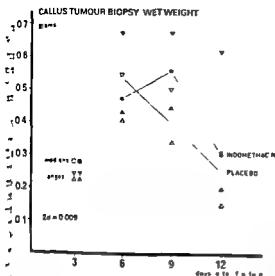


Figure 1 Wet weight of callus tumour. Medians and ranges are given. The difference between the grouped data is significant ($2\alpha = 0.009$)

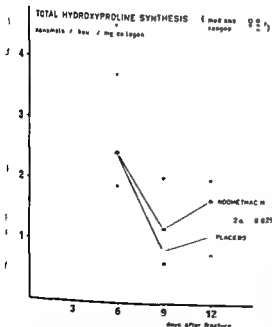


Figure 2 The total *in vitro* synthesis of hydroxyproline in callus tumour. The difference between grouped data is significant ($2\alpha = 0.029$)

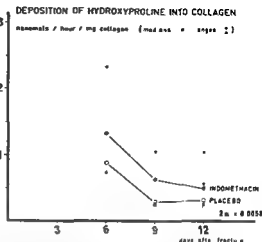


Figure 3 *In vitro* deposition of hydroxyproline into collagen of callus tumour. The difference between the grouped data is significant ($2\alpha = 0.0058$)

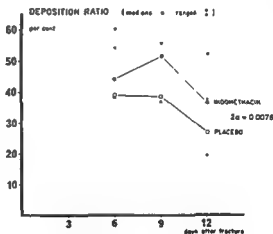


Figure 4 The ratio between synthesized collagen and collagen deposited in the callus tumour. The difference is significant ($2\alpha = 0.0076$)

animals throughout the experimental period, and so is the deposition ratio, i.e., the ratio synthesis of collagen/deposition of collagen (Figure 4) (Flanagan & Nichols 1969).

The *in vitro* resorption of collagen is dealt with in Figure 5. For this parameter there were no significant differences between indomethacin and placebo treated animals.

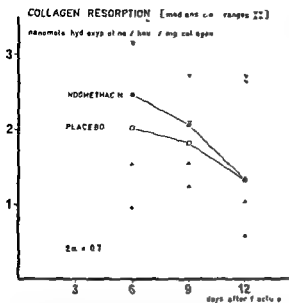


Figure 5 The *in vitro* resorption of collagen (hydroxyproline) from incubated callus tissue. There was no significant difference between indomethacin and placebo treated animals ($2\alpha = 0.7$)

DISCUSSION

In a previous study from our laboratory (Rø et al 1976) an impaired mechanical strength of the same type of fractures in the same type of animals given the same amount of indomethacin was reported. Tensile strength, elastic stiffness and maximal bending moment were all impaired in the indomethacin treated animals. While fracture union was observed

within 18 to 24 days in the control animals, the fractures of the indomethacin treated animals were still unstable at the end of the experiment 24 days after fracture. However, large cartilaginous collars around both fracture ends were found in these animals and

a slit-like cavity was found between the ends. This slit was lined with fibrous tissue and fibrin on days 9 and 12. New bone formation was delayed as compared to the control animals.

The present study deals with the *in vitro* metabolism of the organic component of bone and callus, and it demonstrates clearly that the synthesis and deposition of collagen in callus is higher in the indomethacin treated animals than in their controls. This is consistent with the findings of Alto & Kulonen (1972) and Kulonen & Potila (1973) as far as low doses of indomethacin are concerned, it is to be expected if the primary effect of indomethacin is an inhibition of prostaglandin synthesis (Vane 1971, Raisz & Kooleman, Beynen 1974). However, others have reported inhibited collagen synthesis after indomethacin treatment (Winter 1965, Fukuhara & Tsurufuji 1969) and this might be more easily explained in relation to the impaired mechanical properties of the fractures.

Huusko et al (1975) reported (from a study of tooth extraction wounds) that indomethacin had no effect on the epithelium and the subadjacent connective tissue while bone repair was retarded when treatment was given. This may be consistent with our findings.

As regards the *in vitro* results of the present study it may be argued that if there is a direct effect of indomethacin on bone metabolism the drug may be washed away during preparation of the tissue for incubation. If the *in vitro* metabolism might take place without the influence of indomethacin. However, from Figure 1 and Table 1 it can be realized that callus tumour weight is

Table 1 Collagen content in callus tumour in mg. Medians and ranges are given. Differences are insignificant ($2\alpha = 0.058$)

Days after fracture	n	Placebo	n	Indomethacin
6	8	10.0 (6.9-13.3)	6	11.0 (6.9-21.0)
9	6	17.1 (13.8-18.9)	6	19.0 (13.9-20.2)
12	9	13.6 (8.2-16.0)	9	14.8 (8.8-20.5)

collagen content in callus tumour, both reflecting the *in vitro* metabolism, were higher in the indomethacin treated rats than in the controls. Thus both the *in vitro* and *in vivo* experiments indicate that indomethacin treatment produces a higher rate of collagen synthesis in callus.

The present study suggests that the recently demonstrated impaired mechanical strength of rat femur fractures is not caused by an inhibition of collagen synthesis. It seems that indomethacin treatment produces a collagen of lower quality and some observations might indicate that indomethacin may interfere with the transformation of immature connective tissue to calcified callus and bone. This should be investigated further, as should the possibility of the greater instability of the fractures of indomethacin treated animals may be responsible for the larger callus tumour and at least some of the increased collagen syn-

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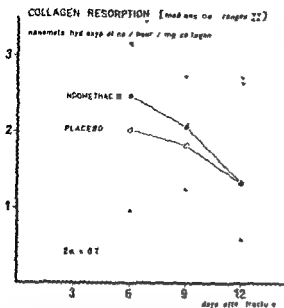


Figure 5 The *in vitro* resorption of collagen (hydroxyproline) from incubated callus tissue. There was no significant difference between indomethacin and placebo treated animals ($2\alpha = 0.7$)

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GLYCOSAMINOGLYCAN METABOLISM IN EXPERIMENTAL OSTEOARTHROSIS CAUSED BY IMMOBILIZATION

ERONEN*, T. VIDEMAN**, C. FRIMAN* & J.-E. MICHELSSON***

Fourth Department of Medicine, H. A. ...

A study was made of glycosaminoglycan metabolism of articular cartilage in developing experimental osteoarthritis caused by immobilization of the rabbit knee. Cartilage samples from various sites in the knee and hip joints were analysed, samples from the mobile limb serving as controls. The concentration of glycosaminoglycans in the tissue was measured by determinations of hexosamine and uronic acid after prior papain proteolysis and subsequent purification. The uptake of ^{35}S -sulphate was used as an indicator of the synthesis rate of sulphated glycosaminoglycans. Metabolic changes characteristic of osteoarthritis, i.e., glycosaminoglycan depletion and increased uptake of ^{35}S -sulphate, were found in tibial weight-bearing and femoral condylar cartilages. Net synthesis of glycosaminoglycans occurred in the tibial marginal cartilage.

Key words: osteoarthritis, articular cartilage, immobilization, glycosaminoglycans, ^{35}S -sulphate

Accepted 6 II 78

The availability of a progressive and irreversible model arthrosis consistently reproducible in animals and recognizable radiographically is of great importance for the study of the pathogenesis of osteoarthritis (OA) and for the evaluation of the various forms of treatment. The immobilization of the rabbit knee in extension as described earlier (Langenskiöld et al 1975) produces a model OA satisfying these demands. In this model, 4 days of immobilization caused a marked increase in ^{35}S -sulphate uptake, indicating an accelerated synthesis of sulphated glycosaminoglycans (GAG) in various articular and periarticular tissues of the knee and hip (Videman et al 1976). After 10 days a histological and macroscopic changes of a degenerative nature could be seen in the

knees. Radiologically demonstrable OA was induced by 4 weeks of immobilization, which, if continued for over 7 weeks, produced irreversible restriction of knee joint motion (Videman et al 1977, Michelsson et al 1977).

Characteristic biochemical changes in articular cartilage in OA are an increased water content (Lindahl 1948), an unchanged content of collagen and a decreased content of GAG (Bollet et al 1963, Mankin & Lippicello 1970, 1971). Biochemical information concerning the initial metabolic changes in developing OA is incomplete. This may be due to the fact that most experimental OA models are more suitable for the study of advanced than of incipient disease. The rabbit model used here produces an OA of a progressive, non-traumatic nature. This is

why it is also well suited for the study of the initial metabolic changes associated with the disease. A loss of proteoglycans and thus of GAG from the cartilage matrix is generally considered an initial change in OA. Hence we decided to study the GAG metabolism of articular cartilage in our experimental OA model with the object of answering the following questions: 1. Is the development of OA in this model associated with changes in GAG metabolism similar to those reported to occur in human OA? 2. How early in developing OA are changes in GAG metabolism detectable and what are these changes? 3. Are differences in GAG metabolism discernible in articular cartilage taken from different sites during developing OA?

MATERIALS AND METHODS

The right knees of 16 rabbits older than 9 months were immobilized in extension by means of a plastic splint (PVC) and by bandaging the knee region with Tensoplast[®] while the hips remained partly movable (Michésson et al. 1977). Six rabbits were used for pilot experiments. Of the remaining ten rabbits, two were killed after 2, 6, 10, 17 and 30 days of immobilization. Twenty-four hours before they were killed, the animals were given 0.26 mCi/kg ³⁵S-sulphate (carrier free, the Radiochemical Centre, Amersham, U.K.) intramuscularly. Samples were taken with a knife from both hind legs, tissues from the left leg serving as control material. Samples consisted of articular cartilage from the following sites: tibial weight bearing region, tibial margin, femoral condyle and femoral head.

The samples were defatted by multiple extractions with acetone, dried to a constant weight at 40°C in a vacuum oven, weighed and digested with papain (Merck 7144) (Wasteson et al. 1972). Proteins were precipitated with 1/3 volume of 40 per cent trichloroacetic acid (TCA). After standing at +4°C overnight the precipitates were centrifuged off and washed once with 10 per cent TCA. The combined supernatants and washings were dialysed against three changes of distilled water at +4°C for 48 hours with stirring. The

4 M hydrochloric acid at 100°C. Uronic acid was assayed with m-hydroxydiphenyl using D-glucuronic acid as a standard (Bhambhani & Asboe-Hansen 1973). ³⁵S radioactivity was measured with a liquid scintillation counter (LKB-Wallac 81000) using automated external standardization for counting efficiency. Radioactivities were reported as dpm/μg hexosamine. Statistical significances were evaluated by the Mann-Whitney nonparametric test. Differences were considered significant when $P < 0.05$.

RESULTS

In the tibial weight bearing cartilage the tissue concentrations of hexosamine ($P < 0.005$) and uronic acid ($P < 0.025$) were significantly lower in samples from immobilized joints compared with the controls (Figure 1a). Tissue concentrations of hexosamine and uronic acid decrease with the period of immobilization, the average hexosamine concentration being 50 per cent and the uronic acid concentration 65 per cent of the corresponding control values after 30 days (Figure 1b). On the other hand, specific ³⁵S activity rises, after a small initial decline, indicating an increased synthesis rate of sulphate GAG. Specific radioactivities reach mean values approximately 100, 150 and 112 per cent higher in immobilized as compared with control cartilages after 10, 17 and 30 days of immobilization respectively (Figure 1b).

In the femoral condylar cartilage the metabolic changes are similar to those found in tibial weight bearing cartilage. Concentrations of hexosamine ($P < 0.005$) and of uronic acid ($P < 0.025$) are significantly lower in cartilage from the immobilized joint (Figure 3a). After only 6 days of immobilization the specific ³⁵S activity of immobilized cartilage is approximately 200 per cent higher than in control cartilage and remains markedly elevated throughout the immobilization period (Figure 3b).

In the tibial marginal cartilage the changes in GAG metabolism induced by im-

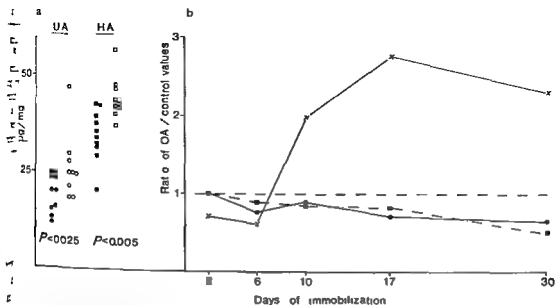


Figure 1 Tibial weight bearing cartilage

(a) Tissue concentrations (μg/mg dry, defatted tissue) of uronic acid (UA)

○ = control values
● = osteoarthritis values

□ = control values
■ = osteoarthritis values

(b) Ratios of osteoarthritis (OA)/control values of parameters measuring glycosaminoglycan metabolism as a function of immobilization time

● = uronic acid
■ = hexosamine
x = ³⁵S activity

immobilization differ strikingly from those occurring in the cartilages described above. Concentrations of hexosamine (*P* < 0.01) and of uronic acid (*P* < 0.05) are significantly higher in immobilized than in control cartilage (Figure 2a). This increase is distinct after 17 days of immobilization and remains so after 30 days. Specific ³⁵S activity of immobilized cartilage increases progressively with the duration of immobilization, being approximately 7-fold, 9-fold and 12-fold higher than in control cartilage after 10, 17 and 30 days, respectively (Figure 2b).

In the femoral head cartilage the concentrations of hexosamine and uronic acid are not affected by immobilization of the knee. Specific ³⁵S activity of cartilage from the immobilized limb, however, is increased about

100 per cent above the control activity after 10 days and remains increased by some 50 per cent throughout immobilization.

The results can be summarized as follows. Immobilization caused an increased specific ³⁵S activity of varying degree in cartilage from all sites studied, i.e., an increased synthesis rate of sulphated GAG. This increase was most pronounced by far in tibial marginal cartilage, where there was a rise in GAG concentration as well, indicating that net synthesis occurred. In tibial weight-bearing and in femoral condylar cartilages immobilization caused GAG depletion, indicating that the GAG degradation rate was increased more than the synthesis rate. In femoral head cartilage the GAG concentration was not affected by immobilization.

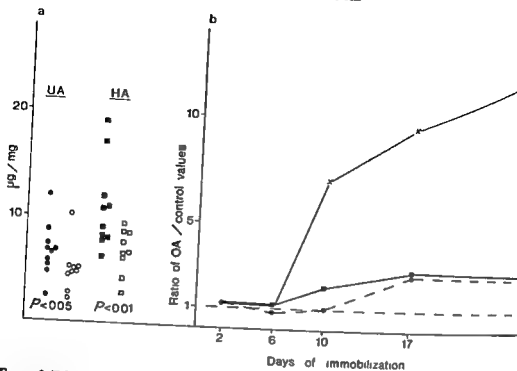


Figure 2 Tibial marginal cartilage
(a) As Figure 1a
(b) As Figure 1b

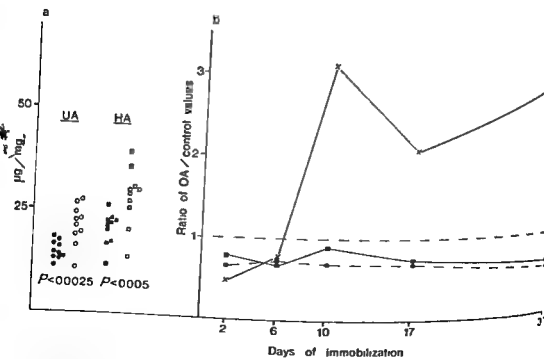


Figure 3 Femoral condylar cartilage
(a) As Figure 1a
(b) As Figure 1b

DISCUSSION

The results show that immobilization of the rabbit knee in extension induces changes in GAG metabolism in weight-bearing cartilage of the knee joint similar to those reported to occur in human OA, i.e., decreased GAG concentration and increased synthesis rate of sulphated GAG. Since these alterations of GAG metabolism are generally considered early events in the development of OA, the model arthrosis described appears appropriate for the study of the pathogenesis and the treatment of OA.

Immobilization of the rabbit knee in extension rapidly produces the changes characteristic of OA in weight-bearing cartilage. After 10 days the GAG synthesis increases some 100 per cent and GAG depletion is discernible. Besides the rapidity of OA induction, other advantages of the present model arthrosis are its simplicity and its non-traumatic nature as compared with surgical manoeuvres employed in the production of experimental OA, e.g., the Hulth procedure (Hulth et al 1970, Ehrlich et al 1975), partial meniscectomy (Moskowitz et al 1973) and anterior cruciate ligament section (Gold & Nuki 1973, Telhag & Lindberg 1977).

The real reasons for the OA changes in the following immobilization are mostly unknown. Immobilization of the knee in extension causes a continuous compression of the weight-bearing cartilages in the joint. This compression may disturb normal chondrocyte function and lead to the changes observed. It has been found that distraction of the joint makes it possible to diminish the OA changes in rabbit knee developing during immobilization (Videman & Michelsson 1977).

An interesting feature is the initial decline in the GAG synthesis rate visible in tibial weight-bearing and femoral condylar cartilages after 2 and 6 days of immobilization, a phenomenon also observed in an earlier study (Videman et al 1976). The immobilization may disturb chondrocyte function

and depress GAG synthesis until degradation of cartilage matrix provides a stronger stimulus leading to increased GAG production by the cells. A normal synthetic rate together with incipient degradation of GAG could also lead to diminished uptake of ^{35}S -sulphate as compared with controls.

Cartilage proliferation peripheral to the edges of the joint cartilage on both the femur and the tibia is found after 10 days of immobilization, and after 14 days definite osteophyte formation occurs on the medial aspects of the tibia (Langenskiöld et al, in press). The finding of net synthesis of sulphated GAG in tibial marginal cartilage reported here agrees well with these morphological observations. The opposite changes in GAG concentrations in weight-bearing and marginal cartilage make it important to determine exactly the sampling regions of cartilage, especially in the fully developed disease, when the weight-bearing cartilage may have almost disappeared. An important future task appears to be the elucidation of the stimulatory mechanisms underlying the hypertrophy of the marginal cartilage of an osteoarthrotic joint.

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FAILURE OF AN ELBOW ENDOPROSTHESIS

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In a patient with a severely damaged elbow, the complication of gas gangrene could be controlled without amputating the arm. However, massive bony defects resulted in a flail elbow joint and an attempt to fit a specially designed endoprosthesis replacement failed. Four years post-injury, the flail joint was fused by three bone grafts on three separate occasions. These experiences are reported and discussed.

Key words: elbow endoprosthesis, gas gangrene, sideswipe fracture, flail joint, metal hinge joint, massive bony defect and arthrodesis.

Accepted 29.xi.77

A specially designed hinge joint was inserted into an elbow joint which had suffered a severe crush injury and subsequently developed gas gangrene. After only one month, the procedure failed. The difficult and instructive reconstruction program is described here.

CASE REPORT

A 23 year-old male machinist, whose right elbow had been broken, was admitted to our clinic on August 19, 1965. A fetid secretion which resembled meat juice was dripping from the roughly sutured wound (Figure 1). An X-ray showed a comminuted sideswipe fracture (Watson Jones 1960) and small gas bubbles (Figure 2). As the complication of gas gangrene was suspected, strict brushing and debridement were performed immediately with administration of antisera and antibiotics. *Clostridium welchii* was cultivated from the secretion.

After a week, a split thickness skin graft was performed on the healthy granulation wound. However, the patient's elbow had become a flail joint, due to massive bony defects, and had to be supported by a light splint. Fortunately the gas gangrene could be controlled without amputation. Thereafter reconstructive procedures began with a pedicle skin graft from his right chest wall on September 9, 1966.



Figure 1 Severely injured right elbow (August 19, 1965)



Figure 2 X-ray of right elbow (August 19, 1965)

On November 18 1966, a specially designed hinge joint made of chrome nickel alloy was inserted into the elbow joint (Figure 3) 22 A is an excellent stainless steel (Cr 19-21 Ni 21-23 Mo 1.5-2.5 C<0.1, Cu 1.5-2.5) which was introduced by Prof. Saburo Iino and Prof. Yunosuke Imai in 1951 (Iino & Imai 1951) and has since been used clinically in Japan.

Postoperatively, the range of passive motion was from 0 to 80°. However a hematoma and a fistula subsequently appeared and staphylococcus aureus was detected. On December 19 1966 the metal joint appeared through the ruptured skin and had to be removed. Thus, the first attempt to reproduce a movable elbow joint had failed.

On January 27 1967, the second attempt involving a functional arthrodesis

was made with bone from the right fibula (Figure 4) and ulna and from the left tibia and ulna. On February 29 1969, when he

Anterior

A stem for the tibia — A stem for the humerus

Figure 3 A specially designed hinge joint made of chrome nickel alloy (22 A)



Figure 4 X-ray of the right elbow after a fibular bone graft



Figure 5 X-ray on August 9 1977. The elbow had united in a functional position.



Figure 6 Making a powerful grip on August 1 1977

threw a snowball his left tibia fractured and placed in a plaster cast which was removed 2 months. In the meantime the elbow had united in a functional position.

DISCUSSION

Nowadays gas gangrene is a rare complication. Only two cases with this complication have been admitted to our clinic during the past 15 years. Primary wound procedure should be strictly adhered to in order to exclude this complication.

In the case of massive bony defects, the most satisfactory results seemed to be achieved by an endoprosthetic replacement. To develop a suitable endoprosthesis of the

bow joint, Roger Dee began a design in London in 1968 (Dec 1976). In reported here, a metal hinge joint for elbow made of chrome nickel alloy (22-A) was inserted. However, this metal joint suffered from three deficiencies: firstly, it was not designed for use with acrylic cements, secondly, its straight rod stem was torsionally unstable in the reamed bone marrow cavity, and thirdly, it was not designed to reproduce the triceps mechanism. Unfortunately, therefore, our first attempt at an elbow endoprosthesis failed.

Although the gas gangrene could be controlled, the subsequent reconstructive procedures induced a post-operative infection. These unfortunate double infections forced us

to postpone any further reconstructive procedures for 4 years.

However, the patient is at present working comfortably.

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COMPRESSION OF THE SUPRASCAPULAR NERVE AFTER FRACTURE OF THE SCAPULAR NOTCH

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A 32-year-old man with a fracture of the scapular notch associated with a lesion of the suprascapular nerve is reported. A nerve decompression operation was performed 20 months after the injury with relief of pain. The possibility that residual disability following a fracture of the scapula can be due to a lesion of the suprascapular nerve is underlined. The value of X-ray examination with projections visualizing the notch and diagnostic local anaesthetic block of the nerve passing through the notch are emphasized. Primary wide resection of the scapular notch is a preferable procedure for preventing recurrence of nerve compression symptoms.

Key words: scapula fracture, suprascapular nerve compression, nerve decompression operation.

Accepted 24.1.78

A fracture of the scapula is uncommon and when it occurs it is often one among multiple injuries caused by a serious trauma (Muller-Farber 1976, Rowe 1963, Zdravkovic & Damholt 1974). The scapular notch may be involved in fractures through the superior lateral angle of the scapula (DeCoulx et al 1956, Edeland & Zachrisson 1975), and is sometimes associated with a lesion of the suprascapular nerve. This mixed sensory and motor nerve originates from the fourth, fifth and sixth cervical nerves, runs through the scapular notch and ramifies to the supraspinatus and infraspinatus muscles, parts of the humeroscapular and acromioclavicular joints and to the scapula itself.

CASE REPORT

A 32-year-old man injured his left shoulder in a traffic accident. X-ray examination showed a comminuted scapula fracture (Figure 1) which he treated with immobilization of the shoulder. During the next 20 months he was treated for recurrent shoulder girdle symptoms with various forms of physical therapy and injections but without improvement.

Arthrography and electromyographic examination (EMG) 15 months after the injury was negative.

Examination 5 months later revealed pain and restricted mobility of the shoulder together with weakness of the shoulder girdle muscles and tenderness in the region of the scapular notch. Local anaesthetic block of the suprascapular nerve in the notch relieved the pain.

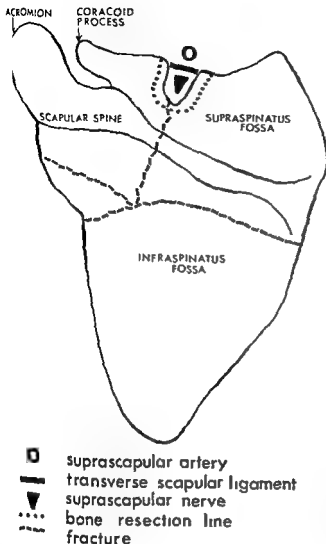


Figure 1 Dorsal view of the left scapula shows the comminuted fracture and the scapular notch with the wide resection of bone

An operation was performed 20 months after the injury through an incision along the upper border of the scapular spine extending the dissection beneath the supraspinatus muscle to the notch, where the suprascapular nerve was seen to be surrounded by a mass of callus. The nerve appeared to be taut and swollen in the proximal section but thin and atrophic distal to the notch. The transverse scapular ligament was sectioned and removed, the nerve released and using a small minimectomy rongeur the notch was widely resected (Figure 1).

The considerable pain in the shoulder was relieved by the operation, but some tenderness of the muscles lasted for several months.

DISCUSSION

Suprascapular nerve entrapment occurs after overstretching of the nerve in the scapular notch with resultant swelling of the nerve which leads to a pain-swelling cycle.

Severe forward flexion injury of the shoulder, especially protraction and forward rotatory movement of the scapula, tether the nerve in the fibro-osseous tunnel of the notch (Rask 1977). Isolated mechanical compression of the suprascapular nerve may give shoulder pain without an obvious cause (Komar 1976).

Edeland & Zachrisson (1975) found, among 18 fractures of the scapula, involvement of the scapular notch in two patients, and in one of these there was injury to the suprascapular nerve. They recommended that a simple antero-posterior projection, with the tube angled 15–30° caudally visualizing the scapular notch, should be included as a routine in the X-ray examination of patients with fractures through the superior lateral angle of the scapula. By conventional X-ray techniques with antero-posterior and lateral projections the notch is not clearly visualized.

Suprascapular nerve lesion in our patient was not suspected until the primary roentgenograms were compared with those from the re-examination. Diagnostic suprascapular nerve block by infiltrating local anaesthetics at the scapular notch (Gordh 1969, Edeland & Stefánsson 1973) relieved the shoulder pain. TV-monitored positioning was used to facilitate both the X-ray examination and the nerve block.

Electromyographic examination of the supraspinatus muscle may show obvious signs of suprascapular nerve involvement (Edeland & Zachrisson 1975). In our patient EMG performed 5 months before the operation showed no pathological findings, but the physical examination, the X-ray findings and the effect of the nerve block suggested involvement. The operation confirmed the diagnosis of nerve compression.

In this nerve decompression operation only the transverse scapular ligament is sectioned. However, we agree with Rask (1977) that primary wide notch resection is a

preferable procedure preventing recurrence of nerve compression symptoms.

This case draws attention to the possibility that residual disability following a fracture of the scapula can be due to a lesion of the suprascapular nerve where it passes through the scapular notch.

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INTERLAMINAR ATLANTO-AXIAL FUSION FOR INSTABILITY

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At the Departments of Neurosurgery and Orthopaedic Surgery in Odense 36 patients were treated with atlanto-axial interlaminar fusion. The operation was performed jointly by the neurosurgeon and orthopaedic surgeon, working as a team, using a specially developed technique. Two bone grafts from the iliac crest were shaped with grooves for the two laminae, and fixed with wire on the right and left side. Postoperative immobilization in a Minerva jacket was maintained for 3 months and a plastic collar was worn for another 3 months.

Twenty-one patients had odontoid fractures, five of them with pseudarthrosis. Ten had atlanto-axial instability caused by rheumatoid arthritis. The instability was horizontal in seven cases, with a mean distance of 12 mm from the odontoid process to the anterior arch of the atlas. Five patients had vertical dislocation with the apex of the odontoid process protruding 8 mm (mean) cranially to the foramen magnum and eight had cord signs. Two patients had an os odontoideum with instability after trauma, and three had other lesions.

At follow-up, at least 1 year after the operation, all fusions were solid, and all fractures but one had healed. The rheumatoid patients had achieved great relief of symptoms with minimum restriction of movement in the cervical spine. The indications for operation on patients with rheumatoid arthritis are very restrictive.

Key words: atlanto-axial instability, rheumatoid arthritis, atlanto-axial instability, atlanto-axial interlaminar fusion.

Accepted 28.11.78

Several surgical methods for stabilizing traumatic as well as non-traumatic atlanto-axial instability have recently been published and are being used with increasing frequency. Indications as well as methods have differed widely, and there has also been an appreciable difference in the results.

At the Odense Hospital we have developed, by collaboration between orthopaedic surgeon (KHS) and neurosurgeon (JH), our own technique which has been used without modification since 1966. The indications, the technique itself, and the results will be reported below.

PATIENTS AND METHODS

From November 1966 to April 1975, a total of 36 patients underwent atlanto-axial fusion. There were 21 males and 15 females with ages ranging from 10-78 years (Table 1). Twenty-one had fracture or pseudarthrosis of the odontoid process, 10 atlanto-axial instability because of rheumatoid arthritis, and two an unstable os odontoideum.

From November 1966 to April 1975, a total of 36 patients underwent atlanto-axial fusion. There were 21 males and 15 females with ages ranging from 10-78 years (Table 1). Twenty-one had fracture or pseudarthrosis of the odontoid process, 10 atlanto-axial instability because of rheumatoid arthritis, and two an unstable os odontoideum. (Grisel 1930), and one patient had hangman's fracture which normally we treat conservatively (Ternansen 1974).

Table 3 Dislocation and angulation in fracture or pseudarthrosis of the odontoid process in 21 patients (cf Table 5)

Dislocation of odontoid process	Forward	Backward	Right	Left	Total
Number of patients	9	5	1	2	15
Medial dislocation					
mean mm	5	7	5	4	
range mm	1-10	3-13	—	2-6	
Angulation (degrees)					
mean	3	9	3	3	17
range	25°	19°	10°	6°	
	20-30°	5-37°	5-16°	3-12°	
Normal position 3					

Table 4 Data for 10 patients with rheumatoid arthritis

	Dislocation of odontoid process		
	Horizontal	Vertical	Horizontal + vertical
10 patients	5	1	4
Mean age 55 years	54-70	63	48-72
Mean duration of rheumatoid arthritis (years)	24	17	21
No. of pts. having cortisone medication (6 mo- 21 yrs.)	3	1	3
Lord or neurovascular deficit signs	5	1	2
Distance (max) from ant. arch of atlas to odontoid process	13	—	11
Range, mm	6-22		8-13

METHODS

When the distance between the atlas and odontoid process was increased, the patient was pre-treated with backward bent head on a double mattress, the upper mattress reaching only to the shoulders. The decision regarding the indications was made jointly by the orthopaedic surgeon and the neurosurgeon and the operation itself was performed by both surgeons working as a team. All the staff must be made aware of the risk caused by the instability.

The patient is anaesthetized and intubated supine, and cranial traction is established (Blackburn tongs) to be on the safe side and to facilitate reduction. Thereafter, the patient is turned over to lie prone, his head on a special head rest fastened to the operating table (Figure 1), and his trunk on a special table used in operations for slipped disc, the median part of the trunk being free. The head is positioned bent 5-10° backward. The neurosurgeon exposes, through a midline incision, the posterior aspect of the atlantic and axial arches and occipital bone

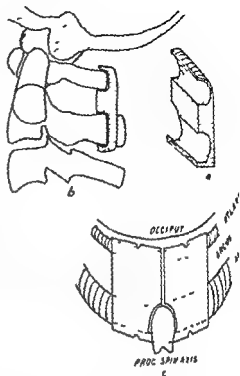
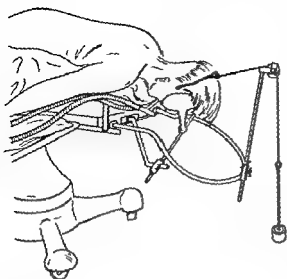


Figure 1 The patient's position on the operating table, his head on the specially constructed head rest. Cranial traction has been established.

Figure 2 The shaping of the grafts and the placement.

behind the foramen magnum and cuts off the compact bone on the posterior aspect of the two arches and III the base of the spinous process of the axis. A spun, stainless steel wire is passed cranio-caudally anteriorly to the arches of the atlas and axis on the right side and another one on the left.

The orthopaedic surgeon removes from the iliac crest posteriorly on the left two bone grafts, about 2 cm wide and about 3 cm long, as required according to measurements, and comprising the lamina externa, half the crest, and underlying spongy bone. In the presence of osteoporosis or slender bones, the lamina interna is included as well. In each graft a groove is shaped just beneath the crest (Figure 2) to fit the atlantic arch, so that the crest firmly grips the upper edge. Farther down, a groove for the axial arch is made, and the bony prominence between the two grooves on the graft fits the distance between the two arches and projects between them. A corner distally-centrally in each graft is cut off at the level of the spinous process of the axis. The middle of the upper and lower edges is notched to accommodate the steel wires which are now tied, on the right and on the left side, so that the grafts are pressed forward into contact with the two arches. Two strong needle holders are used to tighten the wires. The free ends of the steel wire from the right and left side are tied transversely, both above and below the spinous process. This presses the grafts even more firmly, and the two arches cannot be pulled towards each other. The wounds are closed. The patient is laid supine in bed with sand bags at the

sides of his head after the cranial traction has been removed. The patient is taken out of bed to stand twice daily, but is not allowed to move his head. After the sutures have been removed on the 10th day, a felt-padded Minerva jacket is applied. Three months after the operation the patient is readmitted for removal of the plaster cast and lateral tomography. If union has occurred, he is discharged with a plastic collar to be worn for 3 months and after radiography during anterior and posterior bending to secure stability he is given brief instructions for training of the cervical and occipital muscles. One year after the operation he attends a clinical and radiological follow-up examination.

In two patients with fracture of the odontoid process, C_2 , was included in the fusion (acromioclavicular synostosis of C_2 , C_3 , and C_4 , fracture of lateral occipital condyle). In 21 cases the grafts consisted of only half the thickness of the iliac crest and in 15 cases full thickness iliac bone was used. Four of these latter patients had rheumatoid arthritis and six had been treated with steroids; two of them had quite severe osteoporosis. In five very old patients a mini-Minerva jacket was applied with plaster plates down the anterior and posterior aspect of the trunk. All plaster casts



Figure 3 Autopsy specimen of a cervical spine treated by spondylodesis 4 months before the patient died. The grafts are solidly fused (cf text).

A Lateral view

B Oblique postero-lateral view

were padded with felt. Five patients with rheumatoid arthritis wore the supporting neck collar for 4-9 months and one for 35 months (severe osteoporosis and a long course of cortisone medication).

RESULTS

Thirty-five patients were seen at follow-up 1-5, mean 2 years 2 months, after the operation. A woman, aged 54, and treated with steroids for 15 years because of rheumatoid

arthritis, died 4 months after the operation of pulmonary embolism, preceded by two attacks of pneumonia. At autopsy the upper part of the cervical spine was removed. There was solid union at the site of the spondylodesis (Figure 3).

All the spondylodeses had united (Figures 4, 5). In one patient odontoid non union was still present 13 months after the operation, but this was of no clinical significance, as the spondylodesis was solid. In a 77-year-old patient only the posterior

Table 5 Position of odontoid process after healing of the spondylodesis (cf Table 3)

Dislocation of odontoid process	Forward	Backward	Right	Left	Total (preop)
No. of patients	1	2	0	0	3 (14)
Lateral dislocation (mm)	3	2-6	—	—	
No. of patients	1	8	1	3	13 (14)
Angulation, mean	19°	19°	6°	6°	
Angulation range	—	18-27°	—	6-12°	

Normal position 8 patients (preop 3 patients).



A

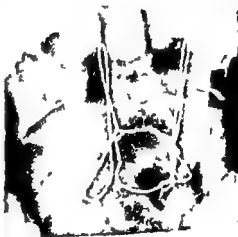


B

Figure 4 70-year-old woman with a 20-year history of non steroid treated rheumatoid arthritis
A Lateral view prior to operation. The distance between the odontoid process and the anterior arch of the atlas is 14 mm
B Lateral view 35 months after the operation. Spondylodesis solidly healed. Odontoid process in the normal anatomical position



A



B

Figure 5 22 year-old man with a high cervical fracture of the odontoid process
A Lateral view 25 months after the operation shows solid healing of the spondylodesis as well as odontoid process. The odontoid process is displaced backwards 15°
B Anteroposterior view illustrating the placement of the steel wires

arter of the odontoid fracture had united 1 year after the operation. In one case one of the grafts took almost 2 years to unite with the atlas, but this did not involve symptoms or a prolonged period of wearing a collar.

In the odontoid fractures considerable improvement of the position was obtained (Table 5) and in five cases there was a normal anatomical position. Sixteen of the patients with odontoid fracture were symptom free, four had mild, periodical fatigue or pain at the back of the neck, and one had constant pain (This was a 77-year-old woman in whom the odontoid process had been tilted backwards 24° , and the fracture had united only in the posterior one-quarter. She exhibited severe spondylosis around the 5th disc and osteoarthritis in all small joints as well as the joint between C_1 and C_2). There were no sequelae to the neurolesions. Seventeen patients had gone back to work an average of 7 months after the operation, while four were still on pension.

Six of the nine rheumatoid arthritis cases seen at follow-up had been largely relieved of their symptoms of atlanto-axial instability. Two had mild pain periodically or a feeling of stiffness. The cord signs had disappeared or considerably decreased except in one case. Tomography showed solid healing of the spondylodesis in all. The horizontal dislocation of the odontoid process had been abolished in five, and in the others the mean distance from the odontoid process to the anterior arch of the atlas was 7 mm (5-10) as compared with 11 mm prior to the operation. Central dislocation had been reduced by 2-4 mm in two patients, but was unchanged in the others. In one patient the odontoid process was tilted backwards 20° as against 23° before the operation (in relation to a plane through the anterior and posterior atlantic arches). Two patients died 15 and 41 months after the operation, so that a total of three of these ten patients in a fairly poor condition died, all of causes unrelated to the atlanto-axial instability.

The spondylodeses had healed solidly in five patients with various more uncommon diseases, and all of them were working. One with an os odontoideum and instability following trauma still had pain at the back of the neck and in the left arm as well as disturbances of sensibility down to the ring and little fingers. The spondylodesis had healed, with the odontoid bone tilted forwards 18° and displaced 5 mm to the right and 7 mm forward together with the entire axis in relation to C_1 . At the operation 7 months after the trauma it had been impossible to improve the position. The spondylodesis was found to have extended to C_2 2 years after the operation.

Mobility in the cervical spine in young patients having an otherwise normal cervical spine was in fact normal, but in elderly patients with degenerative changes it was restricted, in a few to a troublesome extent.

There were no infections, problems of wound healing, or thromboembolic complications. There were no calcifications of the soft tissues surrounding the spondylodesis, no steel wires had broken, and there were no local symptoms. In one case the wing of the iliac bone fractured 2 weeks after the operation, close to the donor site, but there were no late sequelae.

DISCUSSION

Indications After conservative treatment of unstable odontoid fractures there is a great risk of non-union. In cases of high fractures as many as 36 per cent do not unite (Anderson & D'Alonzo 1974), but regardless of the site of the fracture, non-union is common (Schatzker et al 1971 61 per cent, Ramadier et al 1976 35 per cent). In non-dislocated fractures Schatzker et al demonstrated non-union in 42 per cent, in posterior dislocation in as many as 89 per cent. The frequency of life-threatening complications in cases of instability has not been reported, but a few authors have described

such cases (Hentzer & Schalmitzek 1971). Recent publications have therefore justly advocated fusion in atlanto-axial instability, if a reliable result is not obtained by conservative treatment, as this can prevent life-threatening complications to which these patients are easily exposed in modern road traffic (Schatzker et al 1971, McGraw & Rusch 1973, Anderson & D'Alonzo 1974, and others). In doubtful cases we have assessed the stability by forward and backward bending while manual traction is exerted on the skull by an experienced orthopaedic surgeon or neurosurgeon during fluoroscopy.

Atlanto-axial instability has been demonstrated in 25 per cent of hospitalized patients with rheumatoid arthritis (Conlon et al 1966), and fatal cord compression is more common than previously assumed (Mikulowski et al 1975). Among 130 patients with rheumatoid arthritis and atlanto-axial instability, but without neurological deficit, Smith et al (1972) found 5-14 years later that 52 had died, 4 had cord signs, and 6 had symptoms of vertebral artery ischaemia. As the instability most often gives rise to symptoms at the most severe stage of the disease in very disabled patients, most authors reserve operation for patients who develop cord or vascular deficit symptoms or increasing pain and stiffness despite conservative treatment (Meijers et al 1974, Ferlic et al 1975, Thomas 1975, Brattstrom & Granholm 1976, Jones & Kaufmann 1976), especially if the symptoms progress or if acute, neurological episodes occur (Rana et al 1973). We have acted on similar principles. In the presence of severe osteoporosis, we have abstained from operation.

Technique Gallie (1939) set down the principles for stabilizing instability in the cervical spine, viz. fixation of the two involved vertebrae by steel wires and simultaneous insertion of bone grafts from the ilium or tibia. Gallie used this principle with increasing frequency for injuries in all parts of the cervical spine. It has later been designated as a Gallie atlanto-axial fusion,

although he did not accurately describe the technique or report the results. With minor modifications, and with widely different postoperative immobilization (cranial tractors, Minerva jacket, neck collar, etc.) it has been used by many workers (Simmons & Fielding 1967, Schatzker et al 1971, McGraw & Rusch 1973, Anderson & D'Alonzo 1974, Fielding et al 1976, Ramadier et al 1976).

Others have used occipito-cervical fusion with grafts fixed to the occipital bone and C_2 , or possibly C_3 (Patte & Rose 1966, Grantham et al 1969, Newman & Sweetnam 1969, Meijers et al 1974).

Instead of bone grafts Kelly et al (1971) used acrylic bone cement and steel wires to fix C_1 - C_2 , whereas Brattstrom & Granholm (1976) use this for occipito-cervical fixation but these materials include cases complicated by infection or broken steel wires, and the results can hardly be assessed definitely as a longer follow-up period has passed.

The results of atlanto-axial fusion by single bone graft (Gallie fusion) are said to be good, with few complications and rather few cases of non union. Simmons & Fielding (1967) obtained union in all their 35 cases. Schatzker et al (1971) in 13 out of 15 (two in 9 cases the fracture of the odontoid process did not heal, but this was of subordinate importance), McGraw & Rusch (1973) in 14 out of 15, and Anderson & D'Alonzo (1974) in 11 out of 18 cases. Ramadier & Aleon (1971) obtained healing in 93 per cent of 90 operated cases (64 atlanto-axial, 25 occipito-cervical) and Fielding et al (1976) in 44 out of 45 atlanto-axially fused and in 9 out of 10 occipito-cervically fused cases.

After occipito-cervical fusion Patte & Rose (1969) reported healing in 12, Newman & Sweetnam (1969) in 9 and Grantham (1969) in 8 out of 9, whereas Meijers et al (1974) had healing in 11 out of 12 operated patients (one patient died postoperatively). Brattstrom & Granholm (1976) have reported earlier results in 21 out of 28 operated patients for whom they used acrylic bone cement and occipito-cervical steel wire fixation.

the various materials the position of the odontoid process and axis in relation to the C₁ has not been systematically described. The healing of the spondylodesis. By our technique the desired position is obtained. The use of the interposition of the graft between the arches of C₁ and C₂, and extra stabilization is afforded by the two grafts meeting at an angle with each other. Our material confirms that the surgical treatment of atlanto-axial instability can be achieved devoid of complications and its results are reliable. However, the indications for operation will remain strict in the case of patients with rheumatoid arthritis owing to their already poor prognosis.

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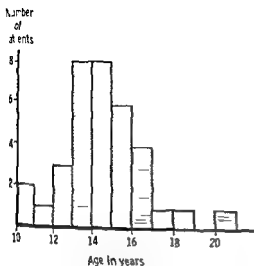


Figure 1 Histogram showing the age distribution of patients at the time of operation (35 patients)

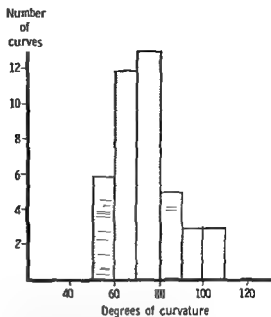


Figure 2 Histogram showing the distribution of curve angles before operation, measured by the method of Cobb

braces. A final distraction of the spine was accomplished. The brace is worn constantly for 1 year. For an additional 6 months a supporting abdominal corset is used. One and a half years after the operation the patients are allowed to move about freely and to participate in physical activities.

RESULTS

The patients' ages at the time of operation are shown in Figure 1. The mean age was 14 years. One patient was operated upon after cessation of growth - 21 years of age. The mean period of observation before the operation was 4 years. For patients with adolescent idiopathic scoliosis, the mean

period of observation before the operation was 2½ years. Some of the patients were observed initially at other orthopaedic clinics.

Preoperatively the Milwaukee brace had been used in 23 of the 35 patients. The preoperative curve varied between 51 and 106° the average being 74° (Figure 2). The mean correction afforded by the operation was 33°, corresponding to a correction of 45 per cent. This correction varied from 13 to 61 per cent. In the 1st year after the operation the average loss of correction was 8° varying from 0 to 22°. In six cases the hook slipped one notch down the Harrington rod. This in four cases

Table 2 Results in 42 curves

	Degree			Percentage of preoperative curve		
	min	max	average	min	max	average
Initial correction	10	51	33	13	61	45
Loss in Milwaukee brace during post-operative year	0	22	8			
Loss after removal of brace	0	9	0.7			
Total loss	0	22	8.7			
Final maintained correction	1	46	24	1	51	33



A Before operation

B On the day of the operation

C 4½ months after the operation

Figure 3 13 year old girl with an idiopathic scoliosis

The initial curve measured 66° . The curve was corrected to 29° . 4½ months later the curve had returned to 40° . Note the changing position of the lower hook on the neural arch

contributed to a loss of correction from 11 to 22° during the 1st year. In other cases the lower hook changed its position on the neural arch and this may have contributed to a loss of correction (Figure 3). After the 1st year the loss of correction was minimal averaging 0.7° .

At the final follow up from 1½ to 4½ years after the operation average 2½ years, a mean correction of 25° or 33 per cent had been obtained (Table 2).

Complications were few. One patient had a transient paresis of the right leg and another patient a transient sensory disturbance. Pseudarthrosis was not observed. In four cases the initial correction was minimal because the scoliotic curve was very rigid.

This applied to three cases of idiopathic scoliosis and to one case of congenital scoliosis only. In one case an idiopathic scoliosis a correction of only 13° was obtained. During distraction the upper neural arch fractured so that the hook had to be placed one vertebra higher.

DISCUSSION

An initial correction of 45 per cent or more responds with that obtained in materials such as Pigott's (1976) and Bjerkreim's (1977) while in other materials a larger initial correction was obtained (Nordwall (1973), 64 per cent; Goldstein (1969), 64 per cent; and Dickson & Harrington (1973), 64 per cent).

reason for a larger initial correction may be a smaller initial curve, which means lesser duty and lesser rotation and makes a later correction possible (Goldstein 1969). Therefore it is recommended that the patients be sent to a qualified orthopaedic surgical department at an early stage.

A certain loss of correction after the operation will occur as a result of growth of the spine. The postoperative loss of correction reported varies (Goldstein (1969), 3.2 per cent, Leider et al (1973), 5°, Nachemson 1976) 6°, Bjerkreim (1976) 6.5°, and Ekson & Harrington (1973), 8°). In this series the loss averaged 8.7°.

There were two essential reasons for loss of correction, disengagement of the upper hook of the Harrington rod in six cases, and in three cases displacement of the lower hook on the neural arch (Figure 3). Both Pigott (1976) and Bjerkreim (1976) have reported a considerable loss of correction in cases where the locking wire is omitted. The locking wire is used routinely.

In all the patients a cloudy structure of the ossified mature bone, corresponding to the chips, was seen at the 1-year check-up. In no cases of pseudarthrosis were detected on ordinary X-rays. There have not been any cases of deep infection or of deep thrombosis. The final improvement of 33 per cent of the initial curve corresponds with results obtained by others (Nordwall 1973, Pigott 1976 and Bjerkreim 1976) and thus result is obtained with few actual complications. All patients had a visible, but acceptable rib hump after the operation. Only a modest rotation, measured according to Nash & Moe (1969), took place at the operation.

One compares the results of today, using the Harrington instrumentation technique, with the earlier operative treatment (Buus & Pilgaard 1977), a considerable improvement concerning maintenance of curve correction is seen.

After conclusion of this material the postoperative period of bed rest has been shortened to 2-3 weeks, and this has not

changed the results. Using Harrington's instrumentation technique, with posterior fusion and a Milwaukee brace for 1 year post-operatively, a good correction of severe scoliotic curves may be obtained, without major complications. It is, however, desirable for scoliosis patients to be operatively treated before the curve becomes too severe (about 50-60°).

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At the final follow-up, from $1\frac{1}{2}$ to $4\frac{1}{2}$ years after the operation, average $2\frac{1}{2}$ years, a mean correction of 25° or 33 per cent had been obtained (Table 2).

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engaging different nervous structures, from peripheral nerves up to central structures in the brain (Robin 1975). Another symptom of these diseases may be a disturbed equilibrium function.

Posture and postural control

The equilibrium in upright posture is dynamically controlled, and a slight postural sway is a normal phenomenon. The postural sway occurs both in the sagittal and the lateral plane and represents a complex reflex process, involving acquisition and processing of sensory information as well as execution of motor commands. The input information originates from proprioceptors in the muscles, joints, ligaments and tendons, and from the vestibular and the visual apparatuses. Postural reflex activity can be initiated in the proprioceptive system at the spinal level. Much of the input concerning postural equilibrium is co-ordinated into proper motor commands at supraspinal centres through a continuous integration of impulses from the different receptor systems. The vestibular system, the reticular formation, and the cerebellum form a functional group at the brain stem level which is of vital importance for postural equilibrium control. More demanding sensory processing involves the basal ganglia and also the cerebral cortex (Redrickson et al 1966, Guyton 1976, Martin 1967, Nashner 1970, Roberts 1967).

It has often been shown that the complex regulatory process of postural equilibrium can be disturbed by various neurological disorders involving different levels in the central nervous system.

Techniques for studying postural sway

A number of methods for studying the act of standing have been described in the literature, but none is free from criticism. In principle, any method or combination of methods that records information pertaining to the control process and the performance can be used. For obvious reasons, the external

recording sites must usually be selected and the methods narrowed down to kinesiological techniques, i.e., methods of studying movements by means of film photography, electromyography, and measurements with accelerometers and force transducers, etc. These methods have recently been reviewed by Grieve et al. (1975). In stabilometry a force platform of varying design is the most frequent recording instrument (Terekhov 1976). The force platform responds to the projection on the horizontal base plane of the movements of the body's centre of gravity, which are inevitably present while standing. For evaluation, the lateral and sagittal sway amplitudes and centre and size of the sway area (Njokiktjen & de Rijke 1972) and other statistical signal characteristics, e.g., power spectra, are often estimated (Bensel & Dzendolet 1968, Cernacek et al 1973, Eklund & Löfstedt 1970, Leroux et al. 1973, Scott & Dzendolet 1972). Other measures, subjective as well as objective, are also frequently used.

The use of force platforms in studies of postural sway has several advantages. The test procedure is simple, and very easy to explain to the subjects. It can readily be adapted to give prominence to specific aspects of the postural control mechanisms (Tourtelotte et al 1965), and the recorded signals can be evaluated quantitatively by means of electronic signal processing equipment. The mechanical analysis of the results can be involved, however, because of the large number of degrees of freedom of movements of the body (Murray et al. 1967). Since the force platform responds to movement characteristics closely related to those affecting the physiological receptor systems, the test is well suited to an analysis of postural control in terms of control theory and mathematical models (McRuer et al 1968, Nashner 1970, Paltser & Agashyan 1974).

Aim of the present study

The aim of the present investigation was to study quantitatively, by means of

stabilometry, the postural equilibrium in a group of patients with adolescent idiopathic scoliosis and to compare these results with those obtained in a control group. In addition it was of interest to obtain a qualitative measure of the function in the afferent regulatory systems controlling upright posture.

METHODS

Experimental design

The degree of difficulty of standing in the different tests was varied by having the subjects eyes open or closed and by having a stable or compliant base support. Four tests were used in the recordings in the following sequence:

- 1 Standing on a stable base support with eyes open
- 2 Standing on a stable base support with eyes closed
- 3 Standing on a compliant base support with eyes open
- 4 Standing on a compliant base support with eyes closed

The stable base support was identical with the horizontal and rigid surface of the platform and the compliant base support was accomplished by laying a 10 cm thick piece of foam rubber on the platform.

Experimental procedure

The subjects were allowed to become acquainted with the test procedure. All tests were conducted with the subject naked except for underpants. The positioning of the feet on the platform was always the same with the heels together and the feet at an angle of 30 degrees. In Tests 3 and 4 the piece of foam rubber was fitted to the platform and the subject was assisted in positioning his feet accurately. For the test conducted with his eyes open, the subject was instructed to fix his gaze upon a 10×10 cm reference square placed at a distance of 5 m in front of the platform and adjusted to eye level. The room was artificially illuminated. The subject was also instructed to stand relaxed with equal weight on both feet and with his arms hanging freely along the sides of his trunk. The recording of each test lasted 2 minutes whereupon the subject was asked to sit down on a chair and relax for a period of about 2 minutes before the next test.

As a special study the effects of brace

treatment on postural equilibrium were investigated. The patients participating in this part of the study were tested as follows:

- 1 As all other patients before any treatment.
- 2 In a well fitted brace about 1 week after Test 1.
- 3 At the same time as Test 2 but without the brace when the brace had been off for 15 minutes.
- 4 At a routine follow up about 6 weeks after the brace treatment started.

Recording equipment

The postural sway was recorded by means of a force platform provided with a unit for transducer excitation and signal processing and display. The equipment was especially made for stabilometry by L'Electronique Appliquée Montreuil, France (Baron 1964, Barigault *et al.* 1973). The platform measured 44×44×17 cm and it had a foot guide directing the foot angle (30 degrees) and an enabling centring of the subject in the forward-backward direction. Force transducers were placed in the middle of the sides of the platform. Each transducer consisted of a dynamometer ring and a differential transformer sensing the compression of the ring caused by a vertical force component. The transducer signals were processed electronically to yield two signals, representing sway components in the forward-backward direction and in the left-right direction, respectively. These signals were connected to a FM tape recorder (Racal Thermionic, Store 4) for subsequent analysis, and to an X1-recorder (Houston Instrument Omnigraph E11R 95 TV) for monitoring purposes during the recording. The frequency range of the signal channels was from 0 to 10 Hz.

Defining a co-ordinate system with its origin at the geometrical centre of the platform, its positive y axis forwards, and its positive x axis to the right (Figure 1) calibration of the platform yielded the y sensitivity (torque about the x axis) 0.102 V/cm (0.0100 V/kpcn) and the x sensitivity (torque about the y axis) 0.123 V/cm (0.0121 V/kpcn). The sensitivities were orthogonal and neither of them was affected by the position of the foot guide. The offset and the hysteresis of the platform had a negligible effect on the output signals. The non linearity was less than 5 per cent in the y-direction and less than 7 per cent in the x-direction.

Evaluation procedure

The signals recorded on tape were played back at a speed four times greater than during

ding The signals were fed to second-order, erworth low-pass filters (Hewlett-Packard, 1A) the cut-off frequencies of which were 1x (corresponding to the real time frequency 1x). The outputs of the filters were connected to analogue-to-digital converters of a computer P 15). The sampling frequency for each channel was 80 Hz (real time frequency 20 Hz). After digitalization, the data sequences were displayed on an oscilloscope screen and checked for artifacts and equipment faults, and further reduced into separate files. In this procedure the timing artifacts between the sequences were removed by starting and stopping the tape recorder with markers. The files were named according to subjects and recording conditions. In all, 770 files were recorded, containing about 12 million data words.

The recorded voltages were converted to equivalent length-co-ordinates through division by an overall calibration factor and the weight of the subject. These co-ordinates indicate the locus of the action point — on the platform surface — of a vertical supportive force having a magnitude equal to the weight of the subject. When the acceleration forces are small compared with the gravitational forces, this point indicates the projection of the centre of gravity of the body on the $x-y$ plane. Considering the time series of the length-co-ordinates thus estimated as realizations of an ergodic bivariate stochastic process, statistical parameters characterizing the sway were calculated: mean values and root mean-square values (rms values). The mean values x_m and y_m indicate the position of the centre of the sway and the rms values s_x and s_y indicate the sway amplitude in the lateral plane and in the sagittal plane, respectively. In addition assuming normality, parameters of the confidence ellipse of the joint probability density function of the sway at the level e^{-1} of maximum were calculated (Figure 1). At this level the degree of confidence is 93 per cent. The area A of the ellipse is a statistical measure of the total sway amplitude, which takes a possible correlation between the x and y components into account. The correlation also influences the shape of the ellipse.

adjacent samples (Persson 1974), only every third sample was used in all these calculations. All parameters estimated were treated statistically: mean values, standard errors of the means, and 95 per cent confidence intervals were calculated for groups of subjects — the subjects being assigned to one or more groups according to clinical characteristics. To compare the inter individual

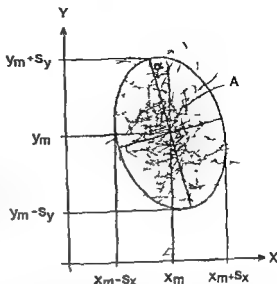


Figure 1 Statistical description of postural sway in the $x-y$ plane. The confidence ellipse of area A has its centre in (x_m, y_m) . The tangents parallel to the coordinate axes yield the standard deviations of the marginal distributions which are equal to the rms values of the sway components s_x and s_y in the lateral and sagittal directions, respectively. The scale of the locus trace has been reduced by a factor of two to increase clarity.

variability with the intra individual variability, the estimated parameters were normalized to their corresponding values in the first test situation. This value was subtracted from the means of co-ordinate and angle values, yielding standard value zero and it was used as divisor with the sway amplitudes, yielding standard value one.

Using the estimated parameters to characterize the various groups, differences between the groups were investigated by means of Student's t -test — assuming equal variances — of the 5 per cent level of significance.

MATERIAL

The study comprised 57 patients with adolescent idiopathic scoliosis (AIS) referred to the Department of Orthopaedic Surgery I, Sahlgren Hospital during the years 1975 and 1976. The controls were randomly recruited from a material of healthy children previously described by Petersén & Eeg-Olofsson (1971). The reason for this recruitment was that the history and the somatic-neurological status in these children had been carefully studied previously. The controls were of

similar age and had the same sex ratio as the scoliotics (Table 1). The 48 patients with single major structural curvatures were subgrouped with regard to the magnitude and convexity of the curvature (Table 2).

Nine scoliotics with double-primary curvatures formed a separate group in this study. These patients had two curvatures of major degree, both with structural changes. The classification of the patients followed the definitions laid down by the Scoliosis Research Society (1976). The scoliotic patients were classified with regard to whether the deformity required treatment or not. All of the patients with double-primary curvatures required treatment. As a rule, the indication for treatment (brace or surgery) was a curvature of more than 20 degrees (Cobb 1948) in a patient still skeletally immature. Two patients, who required a brace and both had a curvature of 17 degrees were the only exceptions to this rule. Eight of the patients with a single major curvature required surgery. The two different subgroups requiring treatment were analysed together and the patients were investigated before any treatment.

Five of the patients with single curvatures and three of the patients among the double-primary scoliotics participated in the special study of brace effects.

The past history was extensively penetrated in all the subjects and they were given a thorough

physical examination with emphasis on neurological status, according to a schedule. None of the patients was taking drugs and all abstained from tobacco and coffee on day of the investigation.

RESULTS

None of the children presented neurological sign of pathological importance in the clinical examination.

Graphical comparison of the lateral and sagittal sway amplitudes, s_x and s_y , and of total sway A are presented in Figures 2 and 3. A summary of the statistical analyses shown in Table 3.

The average position x_m of the lateral sway is to the right of the centre of the support area for the controls as well as in right and left scoliotics. In the right convex patients the shift is significantly more pronounced than the controls. The left convex patients also have a shift to the right, although they do not differ significantly from the controls. The displacement to the right for all these groups is preserved in Test 2. Patients placed under observation have a more pronounced displacement x_m than patients requiring treatment, in both the right and left convex group. This result is statistically significant ($P < 0.05$) for the left convex patients in Test 2.

The sway in the sagittal plane s_y is more pronounced in the scoliotic patients compared with the controls in all of the tests. A common feature is the almost consistently increased degree of significance for the lateral sway s_y compared with the sagittal sway s_x . The significant difference in the sagittal sway — as well as in the other parameters analysed — between scoliotic patients and controls is most conspicuous in the tests from which visual sensory information is excluded. The patients placed under observation were found to have the most pronounced differences in sagittal sway compared with the controls.

Table 1 Material

	Scoliotics (single curves)	Controls
Number	48	32
Mean age (years \pm SD)	13.4 \pm 1.7	13.3 \pm 2.1
Age range	10–16	10–16
Sex ratio δ/ϕ	8/40 (20% δ)	5/27 (19% δ)

Table 2 Grouping of the scoliotic patients with regard to magnitude and convexity

	Patients placed under observation	Patients requiring treatment	Total
Right convex			
Single curve	8	19	27
Left convex			
Single curve	10	11	21
Double primary			
Curve		9	9
Total	18	39	57

* Detailed results in table form can be obtained by applying to Tage Sahlstrand.

Test 3 The right convex patients requiring treatment, on the other hand did not show any significant differences in sagittal sway compared with the controls in any of the test situations.

The scoliotics also had a clear increase in the lateral sway s_x compared with the controls. Another interesting feature is the very marked increase in lateral sway s_x in the tests from which visual information is excluded (Tests 2 and 4). As previously stated, when the scoliotics are compared with the controls the significance is more pronounced in these test situations for the lateral sway than for the sagittal sway. Significant differences under these conditions were also found for the right convex patients requiring treatment. In the lateral sway the difference between the patients placed under observation and the patients requiring treatment became most obvious. The patients placed under observation had a significantly ($P < 0.05$) increased postural sway in Tests 2 and 4 compared with the patients requiring treatment and in Test 4 the right convex patients of these two groups also differed significantly ($P < 0.05$).

The total sway area A is related to the sagittal and lateral sway. Analysis of this parameter also showed results similar to the other ones. One exception is the comparison

between the total group of scoliotics and controls in Test 1. Even in this "easy" test situation a significantly increased sway could be detected in the scoliotic group ($P < 0.05$).

A decreased s_y/s_x quotient compared with the controls, i.e. a lateralization of the sway was noted in Test 4. This finding was valid for the total scoliotic group ($P < 0.05$) as well as for the patients placed under observation ($P < 0.05$) and left convex patients ($P < 0.01$). In comparisons between the scoliotic groups the only significant finding was that left convex patients placed under observation had a lower quotient compared with right convex patients with the same magnitude of curvature ($P < 0.05$).

The average direction of the sway showed significant differences between the groups only in Test 1. The angle α had a negative value in left convex scoliotics. This value is significantly different from that obtained in the controls ($P < 0.01$). The difference persisted when the left convex patients were subgrouped. The right convex patients and the controls had the same value of α . When these patients were subgrouped however the result is obviously a synthesis of a pronounced positive value for the patients placed under observation and a slight negative value for the patients requiring treatment. Statistical comparisons between the scoliotic groups revealed

- Controls ■ Scoliotics ○ Left group ● Right group ▨ Angle α
 □ Stand at place of under obs. group ▩ Stand at place of treatment group
 □ Double group ○ Angle α

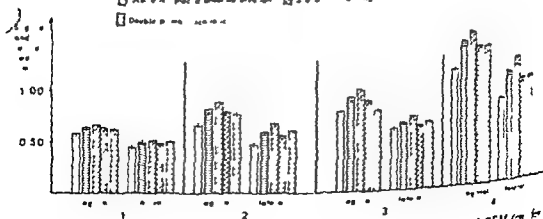


Figure 2 Graphical comparison of sagittal sway s_y and lateral sway s_x . Mean and SEM ($n = 10$) each of the four tests

• Controls

• Scoliotics, total group with single brace

• Scoliotics placed under observation

• Scoliotics wearing treatment

• Right convex scoliotics

• Left convex scoliotics

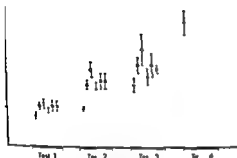


Figure 3 Graphical comparison of total sway area A and SEM (cm^2) for each of the four tests

difference between the right and the left convex patients as total groups as well as between the patients placed under observation or the double-primary scoliotics a significantly increased lateral sway was noted Tests 2 and 4 The total sway was also increased in Test 2 No significant difference was noted in any other test or parameter When investigating the effect of wearing a brace using the total sway area A as a criterion, there were no statistically significant differences either for the test in a well-adjusted brace at the start of the treatment or the test after 6 weeks of treatment

DISCUSSION

Maintenance of upright posture is a complex mechanism and investigation and clinical assessment are rather subjective and non-reproducible Factors such as amplitude and stereopulsion are hardly registered by the clinician (Njokiktjen & de Rijke 1972) small and perhaps subclinical disturbances

may not be detected unless a suitable method and investigation design are available

In designing an equilibrium investigation it is necessary to include tests sufficiently difficult to challenge the nervous system and its neural processing of signals from different afferent sources (Stribley et al 1974) To obtain information about how these different reflex activities are functioning and to obtain a measure of the relative importance of the participating afferent systems, specific experimental situations can be designed. In these the afferent information can be enhanced, weakened or excluded (Eklund & Lofstedt 1970, Gantchev et al 1972 Kapteyn 1972, Lee & Lishman 1975 Murray et al 1975, Stribley et al 1974) Visual input is considered important in the maintenance of postural equilibrium (Gantchev et al 1972, Guyton 1976) Lee & Lishman (1975) even postulated that vision can provide more sensitive information than the proprioceptive system Nashner (1970) found that information from the visual system can be more accurate than that from the vestibular system with a lower threshold for detection of spatial changes of the body in comparison with vestibular sensors. Although visual signals seem to dominate they co-ordinate with labyrinthine receptors in postural control and do not replace them (Nashner 1970) An indirect measure of the importance of visual information for postural control may be obtained by noting changes in postural sway when vision is excluded and included in the test situation.

The characteristics of the base support determine to what extent the vestibular system is involved. With an increasing unevenness in the ground the labyrinthine activity becomes relatively more important (Lee & Lishman 1975, Martin 1967, Njokiktjen 1971, Stahle, personal communication 1977).

The importance of the proprioceptive system increases when visual information is excluded (Gantchev et al 1972, Roberts 1967) Most authors agree that proprioception dominates over the vestibular system as long

the individual is standing on a stable and firm surface (Martin 1967, Nyjokiktjen & de Rijke 1972). The orientation of the body is accurately reflected by the angles of the ankles and from mechanoreceptors that signal the pressure between the feet and the base support. Under these conditions the level of processing can to a greater extent be dealt with at the spinal level in the central nervous system through spinal reflexes (Nashner 1970). However, when the individual is standing on a compliant or unstable surface the proprioceptive information becomes unreliable (Lee & Lishman 1975, Nashner 1970). For maintenance of postural equilibrium under these conditions supraspinal processing is needed to a greater extent. In this mechanism vestibular and visual sensors are involved, integrated mainly at the brain stem level with upwards radiating proprioceptive impulses.

Thus, in the present investigation it may be assumed that the afferent systems have been tested schematically as follows:

- Test 1 Proprioception, mainly at spinal levels, the visual system and to a slight extent the vestibular system
- Test 2 Proprioception, mainly at spinal levels, and the vestibular system possibly more than in Test 1
- Test 3 Proprioception, mainly at supraspinal levels, the visual and the vestibular systems
- Test 4 Proprioception, mainly at supraspinal levels, and the vestibular system to a greater extent than in the other tests

The most striking result of this investigation is the increased postural sway in the scoliotic patients compared with the children with straight spines. This is most conspicuous in the two tests in which the individuals had their vision excluded and had to rely on the proprioceptive and vestibular functions.

With visual input the postural equilibrium is dramatically improved. Whether a stable base support is used or not, the visual information seems important for the scoliotic

patients for improving their postural sway. This finding contradicts a hypothesis that the decreased postural control in the scoliotic group is caused by any important disturbances in the visual system.

There are differences of opinion in the literature about the role of the vestibular system in the test situations used here (Kapteyn 1972). There is general agreement, however, that the vestibular system is involved to some extent in all the tests in the present investigation and that it must be most important in Test 4, i.e. when the subject is standing on a compliant surface with his eyes closed. The statistical analysis did not reveal any difference between the results of Test 2 and Test 4. All the different scoliotic groups had a significantly increased sway, totally as well as in the lateral and sagittal direction. Of course the importance of a more significant contributory vestibular factor in Test 4 may be missed when there are already such clear differences in Test 2. Apart from a disturbed proprioceptive process at the spinal as well as the supraspinal levels, a defective vestibular sensing cannot be ruled out, especially in the scoliotic patients had a lower quotient between the sagittal and lateral sway as they demonstrate the lateralized pattern of the postural sway. This phenomenon has earlier been recognized as a possible sign of vestibular disturbance (Nyjokiktjen & de Rijke 1972).

The differences between the scoliotic patients and the control children cannot be explained by the composition of the material. The age and sex pattern as well as constitutional factors such as weight and height are about the same in the two groups. The investigation was carried out under the same conditions for the patients and the controls. The only exception was that the patients requiring treatment were participating in this study as inpatients. If this circumstance had constituted a "stress" factor influencing the result, these children would have been expected to have a greater postural sway than the patients placed under observation. For the

the contrary, the patients placed under observation participating as outpatients had a poorer equilibrium performance compared with the patients requiring treatment.

This leads us to the question of whether these findings might be of aetiological importance or whether the disequilibrium reflects a phenomenon that is secondary to the deformed spine. If a dysfunction in the postural equilibrium is secondary to the idiopathic curvature, it seems reasonable to assume that a patient with a more severe curvature will have more dysfunction. However, this study has shown a clear-cut difference in all the analysed tests for the patients requiring treatment to have a decreased postural sway compared with the patients placed under observation, i.e., the children with small curvatures. The tendency becomes statistically significant in Test 2 and Test 4 for the lateral sway and in Test 2 also in the total sway. The superior equilibrium performance of the patients given treatment was also evident when these two subgroups were compared with the controls (Table 3). This result is difficult to interpret. It does not, however, support any theory of a postural dysfunction as an effect of a crooked spine.

With a feed back theory as background, the double primary curvatures are interesting to study. Like the patients with single structural curvatures, they turn out to have a significantly increased postural sway compared with the controls in Test 2 and Test 4 and they do not differ from these in the between-group comparison among the scoliotics.

It might be possible that the patients placed under observation and those requiring treatment have been studied in different situations at the time of the development of the disease. The cases placed under observation might have been investigated in an earlier and perhaps more sensitive phase of the disease. This possibility has been considered and a separate analysis reveals that the deformity had been recognized for the same length of time in the two groups. A

brace is considered to stabilize the spine and we know from radiograms that it diminishes the curvature. However, the special study of the brace effect on postural equilibrium did not seem to support the theory that the disturbed postural equilibrium in these patients was caused by the scoliosis. In the tested patients improvement and aggravation were about equally frequent. It seems reasonable to assume that the existence of an active feed back mechanism of any importance would have resulted in a more clear cut tendency towards improvement of postural equilibrium when the patients received their braces.

In summing up the discussion of what is cause and what is effect, we must begin by stating, like so many investigators who have approached idiopathic scoliosis from an aetiological point of view before us, that once a curvature is established it is difficult to say what came first: the different signs or symptoms or the deformity? However, the comparison between the findings in patients with small and more severe curvatures, the results in the double-primary group and the findings in the brace study do not support the theory of the crooked spine as the cause of the disequilibrium in the scoliotic patients. On the other hand, the observations in these patients are not direct evidence that the significant differences in postural equilibrium between the scoliotics and the controls are of aetiological importance. Elucidation of this point requires further study of the outcome for the patients placed under observation in this study. This measure will not be enough, since our material is too small to clearly elucidate this issue adequately. A longitudinal study in a larger group of patients with smaller idiopathic curvatures, still not requiring treatment, is needed to study this issue more thoroughly.

On the whole there are no significant differences in angle values between right and left convex patients except in Test 1. The angle α is a measure of the average direction of sway, and this parameter may reflect such phenomena as rotation and laterotorsion of

the body. This assumption is supported by findings in this comparison, bearing in mind that in the characteristics of the deformity in idiopathic scoliosis rotation is included. When starting from the assumption that the angle α might be a measure of rotation and laterotorsion, the left convex patients seem to have a more pronounced feature of such phenomena than the right convex patients and they also seem to react to a great extent regarding such phenomena when closing their eyes. A different reaction pattern is also found in the s_y/s_x -quotient when left and right convex patients are compared. When the patients are subgrouped according to the magnitude of the curvature, the left convex scoliotics also turn out to have a different pattern in the quotient between sagittal and lateral sway, with a clear lateralization of the sway compared with the right convex patients. It is known (Njokiktjen 1971) that the majority of people have their projection of centre of gravity to the right, as had our controls and right convex scoliotics. An unexpected and somewhat surprising finding is that the left convex patients also had their centre of sway in the lateral plane directed to the right.

Summarizing the comparison between the right and left convex groups, the left convex patients had quantitatively more pronounced reactions than the right convex patients.

ACKNOWLEDGEMENTS

This investigation was supported by grants from The Swedish Medical Research Council (Proj B76-29X 04553 02), Norrbacka Eugenistiftelsen, Bertha och Felix Neuberghs Vålgörenhetsstiftelse, Stiftelsen Sigurd och Elsa Gøjes Minne and Stiftelsen Clas Groschinskys Minnesfond.

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A RATIONAL APPROACH TO THE USE OF EPIDURAL MEDICATION IN THE TREATMENT OF SCIATIC PAIN

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The results of a series of 120 epidural injections given as treatment for backache and sciatica using Methylprednisolone and local anaesthetic are presented and compared with other published results. Wide variations in the results of this treatment were found and these may in part be explained on the basis of the severity of the histological changes known to occur in and around the nerve roots in cases of sciatica.

The pathogenesis of sciatica in lumbar disc disease is discussed in relation to its treatment by epidural injections of a long acting steroid. It is shown that the treatment is more successful in acute onset cases than in those that have epidurals within 6 months of the onset of symptoms. It is suggested that earlier epidurals are given in cases that do not respond to the usual conservative measures. Manipulation of the spine and stretching should not be carried out at the same time as the epidural, as these procedures may adversely affect the results in some cases and certainly make them more difficult to assess.

Key words: epidural, low back pain, Methylprednisolone, sciatica.

Accepted 24.1.78

Sciatica is a common and disabling symptom and the cause of considerable economic loss both to the country and to the individual. The Registrar General's figures show that absenteeism because of sciatica accounted for at least 7 million working days lost in the statistical year 1974-5.

Epidural injections have been used in the treatment of this condition for over 70 years and epidural steroids for over 20 years. Many authors have been very enthusiastic about this form of treatment, stating that it could cure many patients who had had prolonged and unsuccessful conservative treatment and it was instrumental in reducing the operation

rate in lumbar disc disease. Because of favourable reports, epidurals have been increasingly used in the Gloucester Orthopaedic service. The results obtained are correlated with other published results and suggest a more rational use of the treatment which should in turn produce better results.

MATERIAL

An unselected retrospective series of 120 patients treated with epidural injections in the Gloucestershire area up to the end of 1977 was studied. There were 71 male and 49 female patients with ages ranging from 17 to 72 years. All the patients were suffering from "moderate" low-back pain and sciatica, other causes of low-back pain were excluded by appropriate radiological and haematological investigations. From

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patients (37.5 per cent) were suffering from lumbar disc disease with no changes on normal plain radiographs, the diagnosis being based on the history and physical findings. Seventy-five patients (62.5 per cent) were noted to have degenerative changes in their lumbar spine with disc space narrowing. No patient had a spondylolisthesis.

Irrespective of the precise pathogenesis of their root irritation patients were categorized into the following groups on the basis of clinical presentation in order to assess the efficacy of treatment.

- (a) **Acute** Those with an acute onset, no previous history of sciatica and a total history of less than 6 months.
- (b) **Chronic** Those with a gradual onset of symptoms or a history of sciatica of more than 6 months and with a poor response to standard treatment.
- (c) **Recurrent** Those with a history of recurrent attacks of sciatica who had previously been completely cured by conservative treatment.
- (d) **"Radiculitis"** There was a small group of patients who had originally had "acute discs" whose straight leg raising and spinal mobility had been restored to normal by standard measures but who were left with typical sciatic pain.

METHOD

- All patients received 80 mg Methylprednisolone in 20 ml of local anaesthetic (normally Lignocaine 1 per cent) by the lumbar route given in the lateral position with the affected side downwards.

Because this series is retrospective with patients under the care of different orthopaedic surgeons and injections given by several different anaesthetists there were some variations in the medication and method. In particular 70 patients (58 per cent) received in addition to their medication 25 mg of Hydrocortisone Acetate and an ampoule of Hyalase. Thirty-eight patients (32 per cent) had a manipulation of the spine and a sciatic stretch, carried out under general anaesthesia because of the presence of degenerative changes on plain radiograph of the lumbar spine and suspected root adhesions.

RESULTS

These are presented in Tables 1, 2 and 3. Follow-up was 1 year in all cases.

Success is defined as a very substantial improvement as regards pain, spinal mobility and straight leg raising, maintained for the period of follow-up. Failure is defined as either no improvement or an improvement such as to be of little material benefit to the patient. Those patients who gained only temporary or moderate relief, and had to continue with further treatment, were classed as failures.

Fifteen patients (13 per cent) who showed improvement followed by relapse had a second epidural and of these, 6 patients (40

Table 1 Results of epidural injection in the various categories

Category	Total number	Success %	Failure %
All cases	120	62	38
Chronic cases	65	44.5	55.5
Acute cases	31	81	19
Recurrent cases	16	81	19
"Residual radiculitis" cases	8	87.5	12.5
Postlaminectomy	7	28	72
Those with a history of the present attack of pain			
(i) less than 6 months (irrespective of total length of history)	81	80	20
(ii) more than 6 months	51	45	55

Increased success rates in "acute cases" and those with a history of pain of less than 6 months are statistically significant ($P < 0.005$ and $P < 0.001$ respectively on χ^2 test).

Table 2 Results of epidural injection related to X-ray changes

Category	Total	Success %	Failure %
All patients	120	62	38
Those with X-ray changes	75	60	40
Those without X-ray changes	45	63	37

Table 3 Results of epidural injection related to associated administration of Hyalase (H) and Cortisone Acetate (CA), and manipulation under anaesthesia (MUA), and straight leg stretch (SLS).

Category	Number	Success %	Failure %
(a) All cases			
Total	120	62	38
Having H and CA	70	63	37
Not having H and CA	50	60	40
Having MUA and SLS	38	50	50
Not having MUA and SLS	82	67	32
(b) Chronic cases			
Total	65	44.5	55.5
Having H and CA	40	40	60
Not having H and CA	25	44	56
Having MUA and SLS	24	45	55
Not having MUA and SLS	41	44	56
(c) Acute Cases			
Total	31	81	19
Having H and CA	16	87	13
Not having H and CA	15	80	20
Having MUA and SLS	8	63	37
Not having MUA and SLS	23	87	13

There were insufficient "Recurrent" and "Residual radiculitis" cases to analyse separately

None of these differences in success rate is statistically significant

per cent) benefitted from the second injection and were classed as successes

It can be seen that there was a significant improvement in the success rate in patients having their epidural within 6 months of the onset of symptoms and those in the "Acute" category

The presence of degenerative changes on plain X-ray of the lumbar spine did not affect the results of epidural treatment (Table 2)

Variations in medication (Table 3) did not affect the results of the treatment but

manipulation of the spine and acute stretch appeared to worsen the results in acute cases [Thus however just fails to be statistically significant ($P=0.1630$).]

DISCUSSION

Widely differing results have been published by various authors using epidural treatment and it is evident that the medication and the injections are only of secondary

portance Various combinations of saline local anaesthetic and steroid injections have been used and the results differ significantly even in series using the same medication. For example, using small volume steroid injections alone, the success rates are as follows:

Duke et al (1973)	65 per cent
Swerdlow & Sayle Creer (1970)	90.8 per cent
Winnie et al (1972)	100 per cent

It is therefore obvious that the precise pathogenesis of the sciatic pain is of importance in determining the results in individual cases and indeed a perusal of published work shows that very little attempt has been made to relate the results of treatment to the precise cause of the symptoms and this almost certainly accounts for the differences in the results.

Despite these differences however, certain important facts emerge from the published series:

1 The method is safe and indisputably more effective than standard conservative treatment as shown by a controlled trial (Duke et al. 1973).

2 The route of injection (caudal or lumbar) is probably immaterial provided sufficient volume is used to distribute the epidural fluid to the desired level (Swerdlow & Sayle Creer 1970, Mathews & Yates 1969, Goebert et al 1961).

3 In chronic or long duration cases, a steroid preparation is required to improve the results (Swerdlow & Sayle Creer 1970, Beliveau 1971) and there appear to be advantages in the use of a long-acting steroid suspension such as Methylprednisolone (Fishman & Christy 1965, Burn & Langdon 1974, Seghal et al 1963).

4 The use of very large volumes of fluid appears to offer no advantages and may increase side effects, furthermore there is no evidence in the published work that a routine manipulation of the spine or a sciatic stretch improves the results.

5 Irrespective of the medication used the results are better in acute cases and in cases

that have epidurals within 1 year of the onset of symptoms (Swerdlow & Sayle Creer 1970, Burn & Langdon 1970, Winnie et al. 1972, Warr et al 1972).

The precise cause of sciatic pain in individual patients may be difficult to diagnose but whether it is due to mechanical pressure from an acute disc prolapse or chronic osteophyte formation or chemical irritation from abnormal acid metabolites in degenerate discs (Lindhal 1966, Nachemson 1969) there is evidence that the common factor is inflammatory change of variable histological severity in and around the nerve root and perineurium (Lindhal & Rexed 1951).

As these histological changes appear to be progressive, it is reasonable to assume that the earlier a steroid epidural is given the more effective it will be, and that a nerve root infiltrated with chronic inflammatory cells will not be affected by a local steroid injection.

This concept is borne out by the observations from other series already mentioned and also by further observations from the present series, i.e., 81-87.5 per cent success rate in "acute", "recurrent" and "residual radiculitis" cases, 84 per cent of these patients having epidurals within 6 months of the onset of symptoms. There is an 80 per cent success in all patients having epidurals within 6 months of the onset of symptoms. There is only a 44.5 per cent success in "chronic" patients, 61 per cent of these having had symptoms for longer than 6 months when given their epidural.

Conclusions

This series confirms the value of epidural injections in the treatment of sciatic pain. It is felt that while there will always be some failures due to continued mechanical pressure on the nerve root, especially with degenerative osteophytosis, at least some of the failures are due to potentially reversible inflammatory changes in the nerve root being allowed to progress to the stage where they are beyond the help of a steroid injection.

This is confirmed by a statistically significant increase in the success rate in acute cases and those who have an epidural within 6 months of the onset of symptoms. It is therefore felt that

(a) Every effort should be made to prevent the occurrence of established root inflammatory change. All patients with sciatica should therefore be assessed at an early stage by an orthopaedic surgeon. Standard treatment may be instituted but if there is a poor response then an epidural should be given in every case, certainly before 6 months have elapsed.

(b) A long-acting steroid should be used, probably in all cases and certainly in the longer duration cases.

(c) A routine manipulation and sciatic stretch should not be carried out at the same time as the epidural as there is no evidence that it improves the results (the present series in fact suggests that it may worsen the results if carried out in acute cases although these figures just fail to be statistically significant) and it makes it difficult to assess the results of the epidural.

ACKNOWLEDGEMENTS

I would like to thank Mr R Merryweather, Mr D D A Morris, Mr W M Lennox, Mr R A Davies and Mr R J Hart, whose cases I studied for their helpful advice and criticism and especially Mr Merryweather whose original suggestion resulted in the research for this article. I would also like to acknowledge the anaesthetists working at Standish Hospital who carried out the majority of the injections and to thank Mr R S M Ling of the Princess Elizabeth Orthopaedic Hospital Exeter, for reading and criticizing the script and finally to thank Mr J Alexander of Southampton University for his help with the statistical analysis.

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HIP JOINT INSTABILITY AFTER THE NEONATAL PERIOD

Treatment of 20 Consecutive Cases

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A consecutive series of 20 children (21 hips) with idiopathic hip joint instability diagnosed after the neonatal period is presented. The diagnosis was confirmed by hip joint arthrography. In all the children, 15-21 months old at the time of diagnosis, closed reduction could be achieved. They were treated in plaster directly or after treatment of contractures in the adductor muscles of the hip joint.

Stability was rapidly attained during plaster treatment.

The results of the treatment in plaster were checked by a second arthrography in two thirds of the cases, and all cases have been clinically and radiologically evaluated 1-4.5 years after diagnosis. All of the children developed clinically stable hips and they walk normally. In two hips signs of avascular necrosis of the femoral head were found and in three hips (two children) the skeletal development was markedly delayed. In 81 per cent (17/21 hips) the prognosis was considered good; it is uncertain in the remaining four hips.

The appropriate period of fixation in plaster related to the age of the child is discussed.

Key words: arthrography, hip instability, late diagnosis, plaster treatment.

Accepted 6.11.78

During the 1950s, the diagnosis of and abduction treatment for hip joint instability in newborns was introduced into Sweden. In 1963, 99 per cent of all newborns were included in the hip joint examination at the maternity clinics (Palmén 1970). The excellent results of diagnosis and treatment in an urban area (Malmö) have been presented by von Rosen (1970) and Fredensborg (1975). Practically all cases were diagnosed during the neonatal period. On the other hand, materials from Sweden as a whole (Palmén 1975), and from Uppsala University Hospital (Almby & Rehnberg 1977) have shown an unexpectedly high rate of cases diagnosed after the neonatal period.

The value of arthrography in the diagnosis of hip joint instability discovered after the neonatal period has been demonstrated by Severin (1941) among others. Severin's material consisted mainly of children over 1 year of age. As a result of the numerous and efficient Child Care Centres, most cases not diagnosed during the neonatal period are now detected much earlier than before. According to Palmén (personal communication 1977), most cases are now diagnosed before the age of 6 months.

Because the diagnosis and treatment of this group has been somewhat neglected in favour of the newborns, the following study has been undertaken in order to elucidate the diagnosis

and treatment of hip joint instability after the neonatal period. Arthrography has been used to analyse the changes in the joint. Treatment has been guided by this examination.

Definitions

Unstable hip joint Hip joint in which the femoral head III or can be moved out of the acetabulum partially or completely.

Neonatal period The child's first month.

PATIENTS

The series consists of 20 children, all girls. They were born in the county of Uppsala and constitute all of the cases diagnosed after the neonatal period within the county from January 1972 to December 1975. The age at diagnosis was 1.5 to 21 months (Table 1).

All pregnancies followed a normal course, and delivery was normal in 17 cases. In two cases Caesarian section was undertaken and one case required vacuum extraction because of a drawn-out delivery. No breech deliveries were found. All the children were born within the normal time except for two who were overdue by about 1 week. Weight at birth varied from 2648 g to 4690 g (average 3606 g). One Rh immunized child showed a mild neonatal icterus. The others were all healthy.

METHODS

Clinical diagnosis

Maternity Clinic All children were examined by consulting paediatrician with regard to hip joint instability (positive Ortolani's sign) at least once during the first week of life.

Child Care Centres The children were examined by a paediatrician or a general practitioner at existing check-ups, the first of which takes place at about 6 weeks of age and there are three to four further examinations during the first year of life.

Orthopaedic Clinic Consultation was required by the physician in the Maternity Clinic or at Child Care Centre or by another physician. All children were examined with regard to positive Ortolani's provoked instability laxity in abduction, asymmetrical thigh creases, a short and gait disturbances. After a radiological survey of the hip joints, the children were admitted to clinic for further treatment.

The series has been divided into two age groups for this analysis.

- (1) Less than 12 months at diagnosis (16 cases before walking)
- (2) More than 12 months at diagnosis (4 cases after walking)

Radiological diagnosis

Radiological survey of the hip joints. In all cases three examinations are referred to.

- (1) Before any treatment

Table 1 Reason for orthopaedic examination at leading

Reason for examination	No.	Age
1. Check up after exam at maternity clinic	3	1.5, 4
2. Hip abnormality found at Child Care Centre	15	
(a) routine exam.		2, 3
(b)		2, 3,
3. Hip abnormality found for other illness		5

and the most frequent

(3)

- (2) Within 5 weeks of completion of plaster treatment
- (3) The most recent survey 1-4.5 years after diagnosis

At least two films were exposed on each of these occasions

- (1) One a.p. view of the hip joints with the legs extended and rotated slightly inward
- (2) One a.p. view with the legs extended, abducted at least 45° and rotated maximally outward (Lauenstein's position)

At the first examination a test of stability was also introduced in which the legs were extended, rotated inward, and pressed axially

Arthrography, as recommended by Severin (1941) and Lauenstein (1941) was not performed, even in unilateral instability, as was done by Severin (1941) and Lauenstein (1941).

undertaken, even in unilateral instability, as was done by Severin (1941) and Lauenstein (1941).

Standardized projections were used with the children always supine, with the legs symmetrically in different positions. One film was always taken with the legs extended.

A total of 62 arthrograms have been done, all of acceptable quality. The children were examined under general anaesthesia without complications. The criteria suggested by Severin (1941) for a normal arthrogram have been used in assessing our material.

Treatment

In cases where there was little or no limitation in abduction, arthrography was done soon after admission. In 11 hips with a limitation of abduction of more than 20° , traction treatment for 5-25 days was given before arthrography was done. Radiological and clinical findings at

arthrography, which was performed under general anaesthesia, decided further treatment. In 19 of 21 unstable hips reduction was successful; the legs were fixed in a symmetrical hip position mostly while under the same anaesthesia. In the oldest bilateral case, repeated attempts at reduction were required before an acceptable position could be attained. If the limitation of abduction remained after reduction, adductor tenotomy was carried out (Table 2).

In 17 out of 20 cases the position of treatment was 90° flexion and $70-80^\circ$ abduction (so-called frog position). In the three remaining cases, maximal congruency in the joint was attained by 45° abduction and $20-30^\circ$ inward rotation. This position was used for the initial fixation. Later plaster casts were changed every 4 weeks. The length of treatment in plaster was, in the younger age group 13-27 weeks, in the older group 25-29 weeks.

After the period in plaster, treatment was continued with an abduction brace and the children have been followed for at least 1 year after diagnosis.

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RESULTS

Clinical findings at diagnosis

At the maternity clinic The paediatrician noted a positive Ortolani or laxity in four of the children during the first examination. Three of these were immediately referred for orthopaedic examination, and were at that time considered to have stable hip joints. No treatment was started, but continued check-ups at the orthopaedic clinic were considered necessary (Table 1). The fourth case was examined again by a paediatrician 2 and 5 days later, and was then considered to have stable hip joints. (This girl was later referred at the age of 4 months by the Child Care Centre with an abduction limitation, at which time a diagnosis of instability was made.)

At the Child Care Centres Abnormality in the hip was found in 15 cases, including the child mentioned above. In general it was the limitation in abduction (sometimes combined with leg shortening) which led to a

Table 2 Treatment before plaster in 21 unstable hips (20 cases)

Age at diagnosis (months)	<12	>12
Traction/tenotomy	9	4
No treatment	7	1

Table 3 *Clinical findings at diagnosis in 21 unstable hips (20 cases)*

Age at diagnosis (months)	<12 >12	
	No	Total
<i>Unstable hips</i>	16	21
<i>Findings</i>		
Limited abduction	14	19
Leg shortening	10	14
Asymmetrical thigh crease	5	7
Positive Ortolani	5	5
Limp or other abnormal walk	—	5

referral, but other reasons were also given (Table 1 2)

In six of these cases the parents suspected an abnormal condition of the leg (Table 1 2). The four oldest of these children (8, 17, 19, 21 months respectively) had been seen earlier at the Child Care Centre without abnormal findings.

In two children hip abnormality was accidentally found during examination for another illness (Table 1 3).

At the orthopaedic clinic There was a family history of hip joint instability in three cases. In 14 cases the left hip joint was affected, in 5 cases the right. One girl had a bilateral instability. (For other clinical findings, see Table 1 3).

The five hips with positive Ortolani in the younger age group could be reduced without prior treatment. Two of these had no restriction in abduction, which however, was found in the other three and remained even after reduction. All the other cases also had restricted abduction and could not be reduced.

Radiological findings at diagnosis

Survey films of the hip joint showed a cranial displacement of the femur in all cases. In all cases but one there was a retarded ossification laterally in the iliac bone, which gave the acetabular roof a steeper appearance (Figure 1a). In the younger age group (16

cases), the epiphyseal nuclei were not visible bilaterally in seven, they were of the same size in four, and smaller on the unstable side in five.

In the older age group the epiphyseal nuclei were always smaller on the unstable side. In the bilateral case, both epiphyses were smaller than normal at that age.

Arthrography In all cases, the femoral head either spontaneously or by force was displaced cranially and laterally. Maximal cranial displacement appeared either with the leg abducted about 45° and rotated outward or rotated inward under axial pressure (Figures 2a, 3a and 4). It was generally less than 5 mm in the younger age group and more than 5 mm in the older group.

The shape of the femoral head differed from normal in 16 of the 21 unstable hips. There was a variable degree of deformity from a slight flattening in the younger children (Figure 2a) to an obviously oval shape in the older children (Figures 3a and 4).

The cranial part of the labrum acetabolare was always deformed (Figure 2) and sometimes difficult to define (Figures 3a and 4).

The joint capsule was widened in all cases (Figures 2 3a and 4).

In general a good reduction could be achieved (Figure 2b). In the oldest case with bilateral displacement no reduction could be attained in connection with the arthrography. The reason for this was considered to be a residual limitation of abduction, and not an intracapsular obstruction.

Clinical findings after plaster treatment

At the completion of plaster treatment all the hips were clinically stable. No restriction in abduction remained.

In Figure 5 the length of plaster treatment in this series is shown. The length of treatment has differed greatly in the children aged under 6 months. One girl diagnosed at 4 months of age was treated in plaster for 11 weeks, the shortest period of treatment in the series. Two months later a slight restriction



Figure 1a 5 month old girl Before treatment. Arrows (1) indicate axial pressure on the legs Left hip joint unstable with retarded skeletal development of the acetabulum laterally in the iliac bone Femoral head bone nuclei missing bilaterally

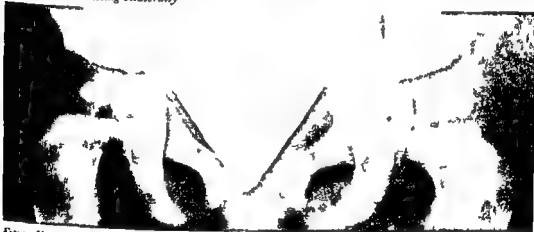


Figure 1b Same girl 9 months old After 14 weeks treatment in plaster for left hip instability No displacement The bone nucleus in the femoral head is small An irregular ossification margin is visible in the iliac bone



Figure 1c. Same girl 22 months old No displacement Bone nucleus in the left femoral head still smaller than the development of the acetabulum normal.



Figure 2 Bilateral arthrography 4 month old girl after 2 weeks traction. Right hip instability.
 (a) Arrows (*) indicate axial pressure on the legs. Max. displacement. Right femoral head is deformed cranially and medially. Labrum acetabulare pushed cranially. Slide joint (Air ball) in the joints accidentally. Metal indicators for stereoradiographic assessment.
 (b) An excellent reduction in frog position.

during outward rotation could be demonstrated. Treatment in an abduction brace was therefore extended to 8 months, following which arthrography showed a normal joint. Continued observation over a period of 16 months has shown the hip to remain normal.

The children have been followed for 1-4.5 years, 11 of them for at least 3 years after diagnosis. All the hips were clinically stable at the most recent check-up with a normal range

of movement. No subjective problems have been reported. No limp has been observed.

Radiological findings after plaster traction.
 Arthrography showed no cranial displacement of the femoral head, even during axial pressure on the legs, in 10 out of 14 examined hips. In four hips (the three older cases) the femoral head could be displaced cranially a maximum of 5 mm.



(a)



(b)

(b) Same girl 2 years old. After treatment in plaster for 26 weeks. Arrows () as in Figure 2(a). Stable femoral head deformity. Labrum acetabulare in normal position. (Metal indicators as in Figure 2.)

Widening of the capsule remained in 10 hips, but was less extensive than at the first arthrography. In these hips the femoral head could be displaced laterally 1–5 mm but only in abduction and outward rotation.

In four hips, the femoral head was normal in shape at this examination as at the arthrography before treatment. In the other 10 the deformation of the femoral head was less pronounced (Figure 3b) but it could still be seen in eight hips.

The labrum acetabulare had a normal position in 10 hips. In the three oldest cases, it was still deformed.

On survey films at the end of plaster treatment, retarded skeletal development was still seen in the previously unstable hip joint. This was most marked in the cases which were diagnosed late. In one case no femoral head nuclei could be found bilaterally at the age of 8 months. In all the other cases, the



Figure 4 Bilateral arthrography. The oldest girl, 2 stability. Arrows (†) indicate axial pressure on the head clearly deformed bilaterally. Labrum acetabuli joints

epiphyseal nucleus was clearly smaller on the previously unstable side (Figure 1b). In one case this was combined with an irregular and flattened epiphyseal nucleus as well as an irregularity in the metaphyseal bone. Only in one case had the acetabulum become completely normal. In the others, the previously demonstrated lateral defect was completely or partially filled, instead, the ossification margin in the iliac bone was more or less irregular (Figure 1b).

During the first year after plaster treatment

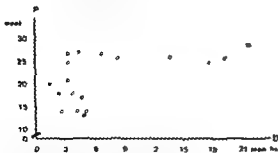


Figure 5 Age at diagnosis (D) in relation to the length of treatment in plaster (P)

Symbols: ○—satisfactory result of treatment
●—relapse of instability
▼—avascular necrosis of the femoral head
x—highly retarded ossification in the iliac bone

skeletal changes of the avascular necrosis appeared in one more case, about 12 weeks after the plaster treatment.

Radiological findings at the most recent examination. One to 4.5 years after diagnosis a situation of continuing favourable skeletal development was noted in 17 out of the 19 previously unstable hip joints, but only two of the girls had completely normal radiographs. The other 14 hips still showed a slightly irregular ossification margin in the iliac bone and/or a smaller head nucleus than on the other side (Figure 1c).

One of the girls with avascular necrosis had only insignificant skeletal changes after 4 years of observation. Four hips were marked by a less favourable skeletal development (Table 4), they are the other 14 with avascular necrosis and three hips in which the mineralization of the acetabulum has been severely retarded (Figure 6).

DISCUSSION

As was noted in the introduction we and our colleagues in Malmö (Southern Sweden) have made great progress in treating



Figure 6 Girl, now 5 years and 2 months old. At diagnosis 17 months old. Left hip joint resected after 3 weeks traction, tenotomy and 25 weeks in plaster stable hip joint. Highly extended contracture in the left iliac bone. The left bone nucleus of the femoral head is smaller and lies a few millimeters further cranially than the right one.

diagnosis. Practically all cases are diagnosed during the neonatal period. This goal has, however, not been achieved in the rest of Sweden. Reports from other countries also show difficulties in connection with neonatal diagnosis (Williamson 1972, MaKenne 1972, Berkman 1974, Nelsen 1977). At the neonatal examination, a variety of clinical instability tests are made (e.g., Ortolani, Barlow or Patten). The problem with these tests is that they sometimes show variable results. This is demonstrated by four cases in this material, which were found to have unstable hips at the neonatal clinic. This could only be verified by the orthopaedic surgeon after several examinations. Clinically and radio-

logically these cases did not, however, differ from the others in the series once the diagnosis was made. Thus it is probable that the other hips also were unstable at birth, but that they were not discovered at this time.

After the neonatal period, the instability is often masked by contractures of the adductor muscle group of the hip. Because of this, the same instability tests are either difficult or impossible to carry out. Limitation of abduction thus becomes the most common clinical sign (Table 7). This can, however, appear without concurrent instability. Radiographs of the hips are then necessary. Delayed mineralization of the acetabulum can be seen quite early in the lateral part of the iliac bone

Table 4 Four hips (3 patients) with obvious skeletal changes at the first radiological examination

Age at diagnosis (months)	Operative time after diagnosis (years)	Slight over-rotation of femoral head nucleus position	Structural changes			Cause
			Caput	Ischial spurs	Acetabulum	
4	3.5	+		+	-	Avascular necrosis
1	3.5	+		-		Late diagnosis
21 (first)	1.5	+				Late diagnosis
		+				Late diagnosis



Figure 4 Bilateral arthrography. The oldest girl & stability. Arrows (1) indicate axial pressure on the head clearly deformed bilaterally. Labrum acetabuli

epiphyseal nucleus was clearly smaller on the previously unstable side (Figure 1b). In one case this was combined with an irregular and flattened epiphyseal nucleus as well as an irregularity in the metaphyseal bone. Only in one case had the acetabulum become completely normal. In the others the previously demonstrated lateral defect was completely or partially filled, instead the ossification margin in the iliac bone was more or less irregular (Figure 1b).

During the first year after plaster treatment

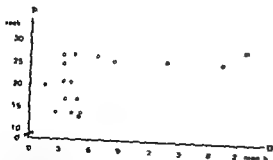


Figure 5 Age at diagnosis (D) in relation to the length of the femoral head. Symbols

- avascular necrosis of the femoral head
- x—highly retarded ossification in the iliac bone

skeletal changes of the avascular necrosis appeared in one more case about 12 years after the plaster treatment.

Radiological findings at the most recent examination. One to 45 years after diagnosis situation of continuing favourable development was noted in 17 out of the previously unstable hip joints, but of these the girls had completely normal radiographs. The other 14 hips still showed a small irregular ossification margin in the iliac bone and/or a smaller head nucleus than on the other side (Figure 1c).

One of the girls with avascular necrosis had only insignificant skeletal changes after 45 years of observation. Four hips were marked by a less favourable skeletal development (Table 4): they are the other hips with avascular necrosis and three hips in which the mineralization of the acetabulum has been severely retarded (Figure 6).

DISCUSSION

As was noted in the introduction we have and colleagues in Malmö (see below) have made great progress in the treatment of

- 3 Restriction of abduction was the most important clinical sign between the neonatal period and the walking age. When a fixed abduction was found, clinical instability could at times only be demonstrated under general anaesthesia after a short period of traction. Even in the youngest cases retarded skeletal development of the acetabulum could be demonstrated.
- i Arthrography is a valuable tool for the verification of hip joint instability, and for finding the optimal position after reduction.
- r The contractures of the hip adductors had to be treated before a good congruency of the joint could be attained.
- ! Treatment in plaster for up to 29 weeks with a change of cast every 4 weeks has been used without great difficulty, and has led to clinically stable hips and a normal gait in all the children.
- 7 With a diagnosis made before walking age, most cases showed good skeletal development of the hip, but avascular necrosis of the femoral head was found in two cases.
- 0 In cases diagnosed after the walking age, radiographs after treatment showed a delayed skeletal development of the acetabulum in certain cases. Arthrography indicated a slight residual instability in these hips although they were clinically stable. This may necessitate operative procedures in the future.

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PHYSICAL PROPERTIES OF FLUOROSIS BONE

Critical Comments

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Key words: bone disease fluoride poisoning statistics physical bone strength tests

In 1976 Franke and co-workers reported a study of the physical properties of bone from patients who had been exposed to fluorine for many years¹. In addition the ash from a rib and an iliac crest was examined and found to contain considerable amounts of fluorine. In the mechanical tests, determinations were made of the fracture load and bending strength of complete bones or parts of bones, and of the fracture load per unit of area and the modulus of elasticity of cylindrical test bodies made from bone specimens.

As the thickness of the femoral cortex was greater in the two patients with abnormal amounts of fluorine in the bone than it was in the three control subjects, the tests on the unmodified bone specimens gave a greater strength for the thicker than for the thinner ones. The specific mechanical tests on the cylindrical test bodies yielded the opposite result, the compressive strength being much lower for the bone from the fluorosis patients. In determinations on the same specimens Young's modulus of elasticity was lower in the fluorosis group. The micro-hardness determined by Vicker's method was likewise greater for these specimens.

So far, so good. But then it was maintained that the observed differences were due to the

fluorosis, and this conclusion is not justified by the results presented. From a statistical standpoint the observed differences cannot be regarded as significant simply because the tests were made on the same specimens. If valid conclusions regarding differences between patient groups are to be drawn from independent observations, the required observations made on one and the same specimen are not independent.

While the observations are considered as information in the literature concerning the properties of fluorinated bone as indicated above, the recorded changes cannot with certainty be ascribed to the fluorosis. What has been demonstrated is only that certain mechanical properties observed in the bone of two persons differed from the mechanical properties observed in the bones of the other persons.

Even if a larger patient material had been available and an analysis of many independent observations had been made, it would have only been justifiable to maintain that fluorinated bone has different properties from normal bone, if it would have remained to be proven that these differences were due to the fluorosis as such and not to, for example, some other factor that was responsible for both the fluorosis and the hardness of the bone.

In a sociological monograph it was shown some years ago that married couples

¹Physical properties of fluorosis bone. J. Franke, H. Runge, P. Grau, F. Fengler, C. Wanka & H. Rempel, *Acta orthop. scand.* 47, 20-37, 1976.

with a large area of parquet flooring in their home were on average significantly happier in their married life than couples with only a small area of such flooring. Even so, no family counsellor would consider prescribing an increase in the area of parquet flooring as a recipe for connubial bliss. Conclusions of this kind are not acceptable in science whether in sociological or in orthopaedic contexts.

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fluorosis, and this conclusion is not proven by the results presented. From a statistical standpoint the observed differences cannot be regarded as significant simply because the tests were made on the same specimens. No valid conclusions regarding differences between patient groups can be drawn from independent observations. The observations made on one and the same specimen are not independent.

While the observations are consistent with information in the literature concerning the properties of fluoridated bone, as mentioned above, the recorded changes cannot with certainty be ascribed to the fluorosis. What has been demonstrated is only that the mechanical properties observed in the bone of two persons differed from the mechanical properties observed in the bones of the other persons.

Even if a larger patient material had been available and an analysis of more independent observations had been made, it would have only been justifiable to maintain that fluoridated bone has different properties from normal bone, it would have remained to be proven that these differences were due to the fluorosis as such and not to, for example, some other factor that was responsible for both the fluorosis and the hardness of the bone.

In a sociological monograph published some years ago that earned much

¹Physical properties of fluorosis bone. J. Franke, H. Runge, P. Grau, F. Fengler, C. Wanka & H. Rempel, *Acta orthop scand* 47, 20-37 1976.

round the prosthesis not exceeding 2 mm (Normal).

The first radiological signs of loosening of the prosthesis are discrete, more than 2 mm wide areas of radiolucency at the sites of maximal weight-bearing (collum and tip of femoral stem). Acetabular wear will show radiolucency in the acetabular roof and eventually osteophyte formation (*Discrete radiolucency*).

A more than 2 mm wide irregular zone of radiolucency around a large part of the femoral stem is indicative of advanced loosening or

By means of patch tests, allergy to chromium, cobalt and nickel was investigated (Evans et al. 1974).

Of the 16 patients, 13 were reoperated on. In 11 patients the prosthesis was replaced, including five after previous fenestration of the femoral cortex. In two patients only fenestration of the femoral cortex was performed. During reoperation, swabs for aerobic, anaerobic and hypertonic saccharose-broth cultures (Kamme et al. 1974 Nolan et al. 1975) and biopsy specimens were obtained from the medullary cavity.

RESULTS

Each of the 16 patients is denoted by a letter.

Table 1 shows the results of the non operative studies. The patients fall into two groups

was determined regularly. An ESR exceeding 25 mm/hour more than 3 months after implantation was regarded as indicative of infection (Sjostrand 1974).

A ^{99m}Tc-pyrophosphate scintigraphy was performed, in patients D and N 6½ months after implantation of the prosthesis, while the others were examined more than 10 months after surgery. One patient (O) was reoperated on less than half a year after implantation of the first prosthesis, thus no scintigraphy was performed.

The scintigram will either show heavy diffuse accumulation surrounding the prosthesis (indicative of infection), discrete but heavy accumulation around a small part of the prosthesis (indicative of a mechanical problem) or very weak accumulation (normal).

Group 1 This consists of nine patients (B, G, I, J, K, L, N, P [and O]) in whom at least two of the three examinations were suggestive of infection and in whom there was good agreement between the radiographic and scintigraphic findings (i.e., the patients in the right upper corner of the table). The diagnosis of infection was

Table 1 The results of radiographic serological and scintigraphic examinations and their interrelation

Scintigraphy	Y ray	Normal	Discrete radiolucency	Diffuse irregular radiolucency	Ostitis	ESR (mm/hour)
Heavy diffuse accumulation		M	C	P L	IBGK N	>25 <25
Heavy, localized accumulation			F	J		>25 <25
Normal		H A E	D			>25 <25

Patient O (with infection) was not subjected to scintigraphy and is therefore not included in the table.

afterwards confirmed in all cases except patient P, in whom re-operation revealed complete loosening of the prosthesis without bacteriological or histological signs of infection. This patient had for a short time been given lincomycin without any change in symptoms or findings (including ESR)

Group 2 This group consists of seven patients (A, C, D, E, F, H and M) in whom none or at most one of the results of the examinations was compatible with the presence of infection. The results in this group are more variable. None of the patients in group 2 has subsequently been found to suffer from infection.

No patient in group 2 had X-ray findings indicative of infection. However, scintigraphy of patients C and M showed heavy, diffuse accumulation around the prosthesis. In patient M the scintigraphic accumulation was caused by allergy but in patient C no reason was found. In only one of the patients with positive findings (F) was there agreement between radiography and scintigraphy and in this patient scintigraphy disclosed the cause of pain: heavy accumulation in the roof of the acetabulum. Correspondingly, reoperation disclosed abundant granulation tissue, presumably

because of too large a prosthesis head. X-ray only revealed slight radiolucency in the acetabular roof and osteophyte formation.

Table 2 shows the most likely cause of inflammation around the prosthesis based on bacteriological and histological findings as well as on radiography, sero-reactions and scintigraphy. Decisive diagnostic importance was ascribed to the bacteriological and histological findings.

The patients were re-examined more than 22 months after treatment of their painful arthroplasty. The results are shown in Table 3. Only three patients were painful. The patients denoted "improved" had no pain on weight bearing, mostly using a cane when walking outdoors and one patient (B) had a persisting fistula. The three patients whose condition had deteriorated had severe pain at rest and very poor ambulatory function. In patient L a Girdlestone arthroplasty was performed 1½ years after replacement of an infected hip prosthesis and the same procedure is planned in patient N. The table shows that only three of the eight infected patients felt better after treatment, which in all cases included antibiotics. Likewise two of the three patients whose discomfort increased unacceptably had an infected prosthesis.

Table 2 The aetiology of the osteitis around the hip prosthesis. The diagnosis was based on as many findings as possible, but if a given patient had undergone re-operation it was based particularly on the bacteriological and histological findings

Aetiology	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Infection																
Mechanical irritation*																
Allergy																
Unknown																
Re-operated																

* Loosening or uneven mechanical pressure

A black rectangle indicates the most probable aetiology and that the patient had undergone re-operation.

Table 3 The results of treatment of failed hip arthroplasty based on interseus with the patients more than 22 months after treatment

Symptoms after treatment	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Well																
Improved																
Unaltered																
Worse																

DISCUSSION

Josseous inflammation around a prosthesis give only very weak X-ray changes within a first year after implantation of the prosthesis (Bergstrom et al 1973, Charnley 1972), partly because of a slow course and partly because some destruction of the surrounding osseous tissue is required before pathological radiolucency can be distinguished radiographically from normal radiolucency. Accumulation on a scintigram is caused by increased metabolism and vascularity (Jones et al 1976). Any noxious stimulus (e.g., infection, allergy and loosening) will very soon cause these principal elements of inflammation. Scintigraphy thus gives a picture of inflammation and does not demand morphological destruction before a positive finding can be registered. A successfully implanted prosthesis will show a normal scintigram after half a year (Bauer et al 1973).

Sjostrand (1974) performed both scintigraphy and scintimetry, and he found that these investigations together gave indications of whether the prosthesis was infected or loosened. Scintigraphy, as performed in this study, reveals the presence of inflammation and where it is situated, but it is not possible to differentiate infection from loosening by the intensity of inflammation.

We find scintigraphy valuable in two situations. When a patient experiences pain

despite an almost normal radiogram (e.g., patients C, F and M), and when X-ray shows radiolucency, to determine whether it is caused by an active or an inert process (e.g., patient D).

In the case of infection, radiography and scintigraphy show identical and diffuse abnormalities. The diagnosis of infection can be confirmed by fenestration of the femoral cortex. This operation may also give material for histological studies (Charosky et al 1973) and cultures (Kamme et al 1974) thus helping to choose the best antibiotic. Further fenestration might relieve pain (Arnoldi & Buhl 1973, Wilson & Scales 1970).

Before reoperation allergy should be looked for.

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SECULAR TENDENCIES OF THE INCIDENCE OF FRACTURE OF THE UPPER END OF THE FEMUR

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and 1975 was calculated taking into account the changes in the size and the composition of the population. It was demonstrated that during the first period the previously described increasing trend continued so that more fractures were observed than could be expected from changes in the population only, whereas later on this trend became insignificant. The changes observed after 1968 could be explained by the increasing number of old residents in the city, and there was no obscure secular trend.

Key words: fracture, incidence, femoral neck

Accepted 6 ii 78

Alfiram (1964) found that during the period 1949-1961 the risk of femoral neck fracture increased in the city of Malmö. The increase exceeded that which could be explained by changes in the age of the population at risk, even when the increased survival age was accounted for, the number of fractures increased over the years. Martenson (1962), also, pointed out that the risk appeared to increase in the city of Gothenburg.

These findings suggest that an additional, so far unknown, aetiological factor is interfering with the incidence pattern.

The objective of the present study was to continue these observations of fracture incidence up to the present time in order to decide whether or not this secular trend is continuing.

MATERIAL AND METHODS

From the records of the Departments of Radiology and Orthopaedic Surgery, all cases of fracture of the upper end of the femur, trochanteric and cervical, in residents of the city of Malmö, were collected for the years 1967, 1968, 1974 and 1975. On the basis of the census data of the city the age and sex specific incidence of the injuries was calculated. The expected numbers of fractures for the years 1967, 1968, 1974 and 1975 were calculated on the basis of the incidence in 1951-1960 assuming that the risk had remained unchanged over the years. By calculating the expected numbers within each 10-year age group the changes in age distribution over the years were accounted for. The observed numbers were then compared with the expected by means of Poisson statistics (cf. Alfiram 1964).

RESULTS

In the period 1951-1960 the average annual number of fractures of the upper end of the femur in the city of Malmö was 132. In 1967-1968 the numbers had increased to 266

and 246, respectively, and finally, in 1974 and 1975 the numbers observed were 331 and 311. There was an appreciable increase in the number of fractures. However, when the observed numbers were compared with the expected, derived from the population figures, and the numbers observed by Alffram (1964) it could be demonstrated that there was a significant continuing increase in the trend between the fifties and 1967-1968 (Figure 1). From that time on the observed number in comparison with the expected did not increase significantly. The age and sex specific incidence is demonstrated in Figure 2. There was a tendency towards a continuing increase in the incidence in the oldest age groups even during the interval 1967/68 to 1974/75. However, the very oldest patients, the octogenarians, were too few in number to contribute significantly to the rising trend, particularly the men. In women, there was a significant trend of an increasing average age at the time of fracture for both cervical and trochanteric fractures (Table 1).

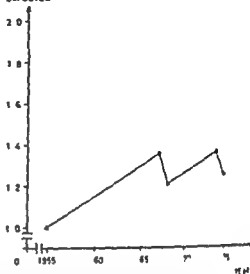
OBSERVED
EXPECTED

Figure 1 The relationship between observed and expected number of fractures of the upper end of the femur. Variations after 1967 are not significant.

Table 1 Mean age at the time of fracture

		1951-60	1967-68	1974-75
Men	Cervical	68.6	71.2	71.7
	Trochanteric	69.4	69.3	71.4
Women	Cervical	71.7	72.7	76.7
	Trochanteric	75.2	76.6	78.0

DISCUSSION

The population background for the increasing number of fractures should be considered. In the city of Malmö over the last two decades, there has been a change in the distribution of the population, as demonstrated in Figure 3. A population peak resulting from a high birth rate at the turn of the century has advanced 20 years, which may be the basic cause of the increasing number of fractures. However, until 1968 the number of fracture in the city increased more than could be explained by the changes in the population only. There is

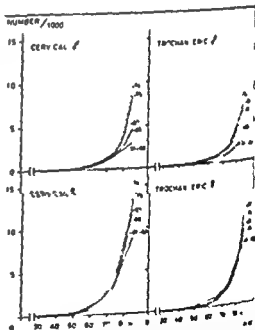


Figure 2 Age and sex specific incidence of fractures of the upper end of the femur. After this there was an increase also during the period 1967-68 to 1974-75 in the oldest group as far as regards trochanteric fractures in women. This increase was, however, not significant.

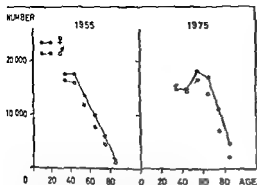


Figure 3 Population of the city of Malmö in 1955 and 1975. A peak value can be seen which is a result of migration and possibly a high birth rate during the second decade of this century. This population peak still has not had its full effect on the fracture pattern in the city.

no valid explanation for this. A hypothesis is that those patients, who had their fractures in the sixties, in many instances had been raised in the city of Malmö in the late phase of the industrial revolution with poverty and in sufficient nutrition whereas a decade earlier persons who then sustained fractures had mostly grown up in the country in southern Sweden and later moved to the city.

Moreover, the effects of poor nutrition in Swedish cities during the 1st World War cannot be disregarded. Alffram (1964) found that fracture of the upper end of the femur is more common in individuals born in the fall than in the spring which indicates that factors such as food and vitamin deficiencies in childhood may be of importance.

It appears as if the rising trend has been broken so that in the future the expected number of fractures may, with some accuracy be calculated from the expected distribution of the population with regard to age and sex and that an increasing number of old residents will have the expected number of fractures and no more. It is of interest to study the incidence changes also in the future.

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UNSTABLE TROCHANTERIC FRACTURES TREATED WITH THE SLIDING SCREW-PLATE SYSTEM

A Biomechanical Study of Unstable Trochanteric Fractures III

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Eighty unstable trochanteric fractures were treated with the sliding screw-plate system. Early weight-bearing was encouraged and mobilization was obtained within the first week in 47 per cent of the cases (37/78). Technical complications were encountered in 5 per cent of the patients (4/78) but none required re-operation. Telescoping of the screw occurred in 43 per cent (37/76). Through this secondary fracture impaction a stable transmission system was established. Fracture union in the post-operative position was obtained in 49 per cent of the patients (37/76) and avascular necrosis did not occur.

Key words: osteosynthesis, rehabilitation, trochanteric femoral fractures.

Accepted 5.3.78

The major problems encountered in the internal fixation of trochanteric fractures are mechanical, especially in unstable fractures (Evans 1949) where the implant alone has to transmit the load from the hip joint to the femoral shaft (Jensen 1978). The load on the hip joint during normal level walking has been calculated to be about six times the body weight (Paul 1971).

The technical complications experienced are either penetration or cutting by the nail due to osteoporosis of the femoral neck and head or bending and breakage of the hip nail-plate due to cyclic loading of the implant, which can also lead to pulling out of the screws. Internal fixation with conventional hip nail-plates of the Jewett type has been followed by technical complications of this nature in 16-31 per cent of cases (Dimon & Hughston 1967, Parker 1955, Robey 1956, Sarmiento 1963, Wade et al. 1959) and with the McLaughlin type in 15-44 per cent of cases (Foster 1958, Friedenberg et al. 1972,

Jensen & Michaelsen 1975, Laros & Wynn 1974).

In 1964, Clawson introduced the sliding screw-plate system for internal fixation of trochanteric fractures and rather encouraging results have been reported recently (Edwards et al. 1975, Harrington & Johnson 1974, Mulholland et al. 1972). In the present series our preliminary experiences with this fixation method will be reported.

PATIENTS AND METHODS

During the period January 1975 to July 1976 the sliding screw-plate system was used in the treatment of 80 unstable trochanteric fractures. The method was applied in fractures classified as unstable either due to lack of posterior or lateral support or lack of medial bone support over the fracture line or a combination of these factors (Evans 1949).

The average age of the patients was 71 years (range 40-95 years) and 45 per cent (36/80) were

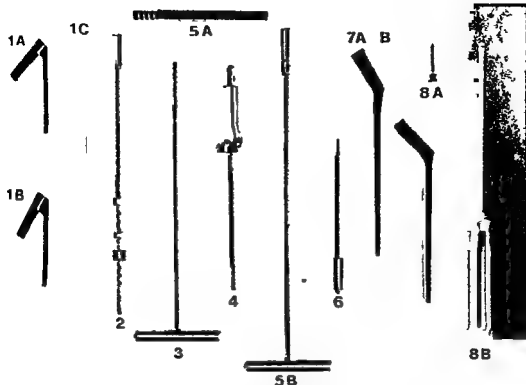


Figure 1 Instrumentation for the insertion of the sliding screw-plate

1 A + B + C 135° angle guide and 150° angle guide with K wire

2 cannulated central reamer

3 cannulated lag screw tap

4 cannulated barrel reamer

5 A hexagonal hip lag screw

5 B cannulated lag screw insertion wrench

6 barrel guide

7 A + B 135° and 150° side plate with 5 holes

8 A + B compression screw with screwdriver

women. Seven patients died within 3 months after the operation giving a mortality rate of 8.8 per cent (7/80). Seventy three patients were followed until fracture union was achieved. In this follow-up series an additional three patients are included as technical complications or telescoping of the screw were encountered before their death.

The operation was performed with the patient supine on a fracture table under X-ray image intensification. After attempted anatomical reduction of the fracture a lateral surgical exposure was made. The instrumentation needed for the internal fixation is shown in Figure 1. A guide wire was passed through the angle guide and drilled through the lateral femoral cortex and the femoral neck into the subchondral area of the femoral head. After measuring the protruding length of the guide wire this was tapped through

the acetabular roof so that it would not be accidentally removed during the following steps. A channel for the screw was reamed and tapped and in addition the lateral femoral cortex was reamed for the barrel of the side-plate. A hip lag screw of suitable length (~1.5 cm less than the distance from the subchondral area to the lateral cortex) was inserted over the guide wire and fastened firmly in the subchondral area. By means of a barrel guide the side-plate was positioned over the screw. In this series the Howmedica Inc. modification (catalogue No 6465-0-000) was used with a barrel-plate angle of 135° or 150°. Rotational stability is secured by an edge in the round barrel and the hexagonal shape of the screw. After having fixed the plate to the femoral shaft the traction was released and compression applied over the fracture line by means of

special compression screw, which was removed after impaction.

In cases with greater medial diastasis in the fracture line a primary medial displacement of the femoral shaft was performed in order to establish bony contact.

Mobilization with full weight bearing was encouraged after the first postoperative period of 2-3 days and postoperative X-ray examinations were performed at 3 weeks, 6 weeks and 3 months. In the follow up study the primary X-rays and subsequent review X-rays were evaluated taking into consideration the technical results.

RESULTS

In the present series 58 screw-plates with an angle of 135° and 22 with an angle of 150° were applied.

The distribution of the fracture types according to Evans (1949) is shown in Table 1, 61 per cent (49/80) of the fractures were 4-fragmentary.

Early weight-bearing was encouraged and Figure 2 demonstrates the time interval before full weight-bearing was achieved, in 47 per cent (37/78) it was within the first week.

The reduction of the fracture was evaluated on the postoperative X-rays and the results are shown in Table 2. In 44 per cent (35/80) of the cases a mechanically stable reduction which allowed load transmission

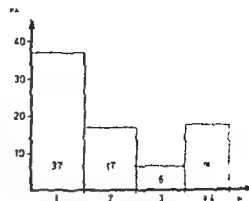


Figure 2 Time interval before full weight bearing achieved (78 patients - 2 days before mobilisation)

through bony contact was obtained. In 17 cases stability was established through medial shaft displacement and in one case through anatomical reduction and screw fixation of the lesser trochanter. In the remaining cases there was a diastasis of more than 0.5 cm at the fracture line.

The results of the follow-up of the 78 patients are shown in Table 3. There was one case of deep infection but no instance of non-union. Forty nine per cent of the fractures (37/76) healed in the postoperative position. Telescoping of the screw took place in 49 per cent (37/76). In 29 of these 37 cases the reduction was considered mechanically unstable as judged by the postoperative X-ray. As a result of this secondary displacement

Table 1 Classification of unstable trochanteric fractures (Evans 1949)

3 fragmentary without postero-lateral support	23
3 fragmentary without medial support	8
4-fragmentary	49
Total	80

Table 2 Radiological fracture reduction in 80 unstable trochanteric fractures

Mechanically stable reduction	35
- screw fixation of lesser trochanter	1
- medial displacement of femoral shaft	17
Medial or lateral diastasis ≥ 0.5 cm	21
Anterior or posterior diastasis ≥ 0.5 cm	24

Table 3 Radiological follow-up in 76 unstable trochanteric fractures

Fracture union in postoperative position	37 (48.7%)
Telescoping of the screw	37 (48.7%)
Technical complication	4 (5.3%)

Table 4 Technical complications in 76 unstable trochanteric fractures

Penetration of the screw head	1 (1.3%)
Cutting of the screw head	1 (1.3%)

The screw head was displaced outside the femoral head.



Figure 3 A, B Postoperative reduction of the fracture. Note anterior diastasis on the sagittal roentgenogram. C Result after telescoping and established bony support after 3 weeks of full weight bearing.

ment of the fracture a stable load transmission system through bony contact was obtained. Figures 3 and 4 demonstrate cases where sliding of the screw took place and resulted in a mechanically reliable system. The telescoping took place within the first 4 weeks in the majority of cases (29/37). The patients often complained of pain during weight bearing in this period.

Technical complications were encountered in 5 per cent of the patients (4/76) as shown in Table 4. In all these patients the screws were placed less than 10 mm from the articular border. Penetration as well as cutting of the screw resulted in a varus angulation of the fracture. In two cases this amounted to less than 10° and to $20-30^\circ$ in the other two. Bony contact, however, was established and the fracture healed in the varus position. No further treatment was needed.

DISCUSSION

Most authors dealing with unstable trochanteric fractures treated with conventional hip nail-plates recommend non-weight-bearing until the fracture has healed (Laros & Moore 1974, Parker 1955, Robey 1956). In the series reported by Jensen & Michaelsen (1975) 15 per cent (25/169) significant mechanical complications (i.e., penetration of the nail, bending, loosening or breakage of the nail or plate) were encountered although a postoperative period of non-weight-bearing of 8 weeks was practised. In the first report on the sliding screw plate Clawson (1964) recommended non-weight-bearing until fracture union was encountered, but later series permitted early weight-bearing (Ecker et al. 1975, Harrington & Johnston 1973, Mulholland et al. 1972, Sahlstrand 1974, Bosacco et al. (1973) and



Figure 4 A Postoperative reduction of 4 fragmentary fracture. Note medial distans. B Telecopied taken place after 2 weeks of full weight-bearing. C Healing result in mechanically stable position.

Sahlstrand (1974) stressed the importance of early mobilization in the treatment of these elderly often debilitated patients. It is possible that the unusually low mortality rate in our series might be a consequence of the early mobilization.

As regards the technical complications following internal fixation of unstable trochanteric fractures the complication rate in series of Jewett nail-plate osteosynthesis has been about 30 per cent (Robey 1956, Wade et al. 1959), although Parker (1955) stated 15 per cent and Dimon & Hughston (1967) as many as 51 per cent. The McLaughlin nail-plate system seems to give slightly better results with complication rates of 15–23 per cent in most series (Foster 1958, Jensen & Michaelsen 1975, Laros & Moore 1974), although Friedenberg et al. (1972) stated 44 per cent. In contrast to this, however, encouraging results have been reported from USA with the use of the sliding screw-plate

system with technical complication rate as low as 4–7 per cent (Ecker et al. 1974, Harrington & Johnston 1973, Mulholland et al. 1972). Friedenberg et al. (1972) encountered complications in 18 per cent in a small series of 27 cases including 4 per cent that were re-operations. In the present series technical complications were found in only 5 per cent of cases (4%). We fully approve of the basic idea of the sliding screw-plate fixation, viz., that a primary stable internal fixation is obtainable in these osteoporotic three- and four-fragmentary fractures. The telecopying allows the fracture ends to impact during weight-bearing until bone support is established across the fracture line. In the present series telecopying of the screw actually took place in 49 per cent of the cases (37/76). Reports on this subject are difficult to compare as no one fracture classification system is generally accepted. In the present

series the Evans classification (1949) was used as it also was in a previous paper by one of the authors (Jensen & Michaelsen 1975). The radiological evaluation was based on the same principles too. In the 1975 series (Jensen & Michaelsen) significant technical complications were encountered in 15 per cent of cases (25/169) following McLaughlin osteosynthesis. This necessitated re-operations in 6 per cent (10/169). In the present series technical complications were encountered in only 5 per cent (4/76) of cases and no re-operations were necessary.

In conclusion we find the sliding screw-plate system to have distinct advantages, because it allows early weight-bearing which is essential for successful rehabilitation and because the telescoping leads to bony support which is essential for the mechanical load transmission.

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Figure 4 A Postoperative reduction of 4-fragmentary fracture. Note medial diastasis. B Telescoping taken place after 2 weeks of full weight bearing. C Healing result in mechanically stable position.

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system with technical complication rates as low as 4–7 per cent (Ecker et al. 1970, Harrington & Johnston 1973, Mulholland et al. 1972). Friedenberg et al. (1972), however, encountered complications in 18 per cent in a small series of 27 cases including 4 per cent that were re-operations. In the present series technical complications were found in only 5 per cent of cases (4/76). We fully approve of the basic idea of the sliding screw plate fixation, viz., that a primary stable internal fixation is unobtainable in these osteoporotic three- and four-fragmentary fractures. The telescoping effect allows the fracture ends to impact during weight-bearing until bony support is established across the fracture line. In the present series telescoping of the screw actually took place in 49 per cent of the cases (37/76). Reports on this subject are difficult to compare as no one fracture classification system is generally accepted. In the present

the edge of the table Dodging was also employed (Levén 1974). The examinations were performed by several different radiologists

Arthroscopy

Our technique of arthroscopy is described elsewhere (Gillquist & Hagberg 1976). Briefly the 5 mm Storz arthroscope (Stille-Werner, Sweden) is introduced into the suprapatellar bursa through the patellar tendon. Sterile water is flushed through the joint by an infusion pump (Sarns Model 5500, Stille-Werner, Sweden) and allowed to escape through a special needle (arthroscopy cannula Stille-Werner, Sweden) inserted into the suprapatellar bursa. Hooks (Gillquist & Hagberg 1976) are used to test the menisci and the cruciate ligaments. Four surgeons performed most of the arthroscopies but about 10 per cent of the examinations were done by another five surgeons under training.

Operation

In all our patients the history and clinical findings indicated arthrotomy, and all were therefore operated on irrespective of the findings at arthrography or arthroscopy.

Comparison of the findings

The findings at arthroscopy and arthrography differed in many respects. The results of the two modes of investigation are compared with the operation findings. A diagnosis was considered accurate when all injuries found at operation had been reported by both arthroscopist and radiologist. However rupture of the medial collateral ligament was excluded in all combined injuries as this was difficult to diagnose by either method especially in old injuries.

Statistical methods

The usual statistical methods were used (Armitage 1974).

RESULTS

Table 1 shows the diagnoses in the entire series as well as in the 90 patients examined by arthrography and arthroscopy in this hospital. The diagnostic findings at arthroscopy and arthrography agreed with the operation findings in 45 cases (Figure 1). In seven knees arthroscopy failed whereas X-ray gave the correct diagnosis. Thus the roentgen

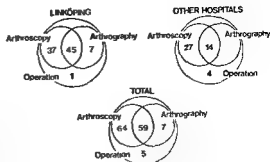


Figure 1 The correlation of findings at arthroscopy and arthrography with the findings at operation.

findings tallied with the operation findings in 52 out of the 90 knee joints operated on (58 per cent). Of the 38 patients in whom arthrography gave an inaccurate diagnosis arthroscopy succeeded in 37. In one patient both X-ray and endoscopy failed and operation was performed on clinical grounds. The arthroscopic findings tallied exactly with the findings at operation in 82 of the 90 patients (91 per cent).

Inaccurate diagnoses

Arthroscopy The diagnosis was inaccurate in eight patients (9 per cent) (Figure 2). Six patients were examined during the first year of the study period, when the failure rate (6/26) was significantly higher than during the rest of the period (2/64) ($P < 0.01$).

The reason for failure was technical in two cases, when we used a 4 mm arthroscope (Storz). In five patients there was a linear rupture of the posterior horn of the medial meniscus. Two patients had a tear of the medial meniscus combined with rupture of the anterior cruciate ligament. In one case the arthroscopy demonstrated the ruptured ligament but not the meniscus tear, and in the other a second arthroscopy disclosed the injuries. In the eighth patient the diagnosis of ruptured medial meniscus was made by arthroscopy (X-ray normal) and at operation

series suggests that arthroscopy should be done when arthrography is negative.

The cruciate ligaments are difficult to examine by arthrography especially in the acute stage. In the present study 35 per cent of ruptured anterior cruciate ligaments were not diagnosed, even though sagittal traction was applied (Liljedahl et al 1966, Levén 1974). A further improvement in the roentgen diagnoses of ruptures of the anterior cruciate ligament has been proposed by Levén (1977a, b), the sagittal instability being measured on films exposed during sagittal traction. Even under direct observation however, a tear may be masked by the synovia, but the lesion is easily demonstrated with a hook.

Arthroscopy has several advantages over arthrography. It is possible to inspect the lesions in conditions such as synovitis (Watanabe et al 1969, O'Connor 1973), chondromalacia and osteoarthritis (Jackson 1974, Gillquist & Hagberg 1976), and acute injury (Gillquist et al 1977), and therapeutic procedures can be performed transcutaneously (Gillquist et al 1976).

ACKNOWLEDGEMENT

The investigation was supported by grant no 55/76 from the Research Council of the Swedish Sports Federation.

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MENISCECTOMY

A Comparison of Two Series Treated as Outpatients and Inpatients

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A total of 129 patients were operated on for meniscus lesion in the knee joint. Of these, 64 were operated as outpatients and 65 as inpatients. The outpatients reported to the operation department in the morning and left the hospital in the evening of the same day, after the operation. The inpatients were admitted to the hospital the day before the operation and were discharged 1-3 days after the operation.

Objective postoperative findings, sick leave periods and the number of visits to the outpatient clinic show no differences between the groups. The end result in the two groups is the same.

This investigation also shows that it is possible to operate on patients with meniscus injury as outpatients without increased discomfort for the individual and without medical risks. Thus expensive nursing resources are released for other groups requiring more nursing care.

Key words: knee joint, meniscus, operation, treatment

Accepted 17 II.78

Patients operated on for meniscus injury require a considerable number of bed-days annually at orthopaedic surgical clinics. According to the literature, the nursing period varies from 3 days to 3 weeks (Smilie 1962, Helfet 1963, McGinty et al. 1977). The patient is usually admitted on the day before operation and discharged 1 to 4 days after.

In order to reduce the load on the nursing departments, we began, in 1974, a policy of operating on, as outpatients, specially chosen patients with meniscus injury. Healthy men 20 to 40 years of age with a clinically and arthrographically verified meniscus injury were usually chosen for outpatient operation. All lived within 30 minutes travelling time from the hospital. It was soon realized that operated outpatients managed just as well as inpatients. Therefore outpatient operation was extended to other age groups.

The object of this study was to determine whether the outpatient operation increased the medical risk and the subjective discomfort of the patients.

PATIENTS AND OPERATIVE PROCEDURE

The study involved 129 patients: 94 men and 35 women. All those operated on as outpatients were studied during a definite period. A control series with the same age range was randomly chosen from among the operated inpatients.

All patients were examined one or more times in the outpatient clinic before the operation. All were X-rayed to exclude skeletal changes. Only half of them (62 patients) underwent arthrography: 35 inpatients and 27 outpatients. At the

Table 1 Age and sex distribution

Age	Male		Female	
	Outpatients	Inpatients	Outpatients	Inpatients
< 20	5	6	2	4
21-30	15	11	5	3
31-40	14	14	7	6
41-50	9	11	2	5
> 51	5	4	0	1

There are no significant differences between the number of patients in the respective age groups (male group $\chi^2 = 2.53$, $df = 4$, $P > 50$ per cent, female group $\chi^2 = 2.73$, $df = 4$, $P > 50$ per cent)

preoperative examination, all were informed about the nature of the injury and of the proposed operation and postoperative treatment. In each group, 46 patients (2/3) were given detailed written and verbal information as to the nature of the injury and treatment including postoperative instruction. Sedimentation rate and Hb-value were checked and blood grouping was done.

The cause of injury was games or sports in 44 cases while 28 patients referred to some other cause, and 54 could not recall any trauma. No difference existed in the distribution of traumatic and non-traumatic injuries between the two groups. Also concerning games and sports, the difference between the groups was insignificant (39 operated outpatients and 30 operated inpatients).

Those operated on as inpatients were admitted to the hospital the day before the operation for normal preoperative examination. They were usually discharged 1-3 days after the operation.

Those to be operated on as outpatients reported in the operation department in the morning and there underwent a final preoperative appraisal by the operating surgeon. After the operation, the patient was kept under observation for 4 to 6 hours and was allowed to leave the hospital after examination by the surgeon. Only one of them asked to be admitted to the nursing department because of considerable pain in the operated knee.

The majority of the patients in the two groups were operated on under epidural anaesthesia, the rest under general anaesthesia.

Except for 14 who were followed up by another doctor, all patients were checked after the operation at our clinic, irrespective of whether they were treated as outpatients or inpatients.

Of the total number of cases, five outpatients and seven inpatients had a concomitant injury to the anterior cruciate ligament and 11 and 18 patients, respectively, showed signs of chondromalacia patellae. Nothing was done about these conditions in connection with the operation.

POSTOPERATIVE FOLLOW-UP

Thirty-two outpatients and 34 inpatients experienced the first days at home as troublesome. Thus there was no difference between the two groups despite the fact that the inpatients had spent 1 to 3 days in hospital after the operation.

During their first days at home 32 outpatients and 25 inpatients needed help from members of their family, and 39 and 35, respectively took pain-relieving tablets. Thus there was no significant difference between the two groups in this respect either.

When leaving hospital, the patients were given crutches and instructed to use them as long as they found it necessary, otherwise they were allowed unrestricted use of the knee. Nineteen outpatients and 16 inpatients used the crutches for less than 5 days, and 50 and 46, respectively for less than 2 weeks.

Of the 39 outpatients and 30 inpatients who took part in games and sports before the operation, 27 and 20 patients, respectively, continued to do so after operation. The practice was usually resumed 7 to 12 weeks after the operation. There was no difference between the two groups.

Table 2 shows the postoperative sick leave period. There is no significant difference between the two groups. Thus, 45 days after the operation, 39 outpatients and 42 inpatients were back at work. The seven patients in each group who were on sick-leave for more than 76 days had apart from meniscus injury, also other changes in the knee joint, such as cruciate ligament injury or chondromalacia patellae.

Table 3 shows the number of visits to the outpatient clinic after the operation. Fourteen patients, however, were advised to report to their local doctor. Patients who reported more than three times usually belonged to the group of multiple lesions and they had the longest period of incapacity to work.

All patients were told that they should un-

Table 2 Postoperative sick leave period in days

Days	No of outpatients	No of inpatients
0-15	8	8
16-30	10	17
31-45	21	17
46-60	12	12
61-75	4	3
>76	7	7
No information	2	1

There are no significant differences between the two groups ($\chi^2=2.35$, $df=5$, $P>50$ per cent)

mediately visit the casualty department if they suffered any discomfort. During the first post-operative week, none of the inpatients and only three of the outpatients did so. Two of the outpatients visited the casualty department because of minor discomfort, which required no medical treatment. A 27-year-old man operated as an outpatient called 7 days after the operation with a deep venous thrombosis in the lower leg. This was treated successfully in the hospital with complete recovery. None of the inpatients required readmission for an acute condition. The case of deep thrombosis was the only postoperative complication in the entire series.

Only 31 patients in each group considered that they were completely recovered 6 months after the operation. Apart from a few exceptions those who did not consider themselves fully recovered thought that their condition did not justify a visit to the doctor. The patients who were still being treated after 6 months belonged to the group with operative findings other than meniscus injury.

DISCUSSION

A comparison of operated outpatients with operated inpatients shows that there are no significant differences between the groups as regards the postoperative course. Both groups experience the first days at home as troublesome, and objective parameters, such as the period of incapacity to work and the number of visits to the outpatient clinic, show slight or no differences. The only post-operative complication, the case of deep lower leg thrombosis, has no connection with the outpatient surgical procedure as such. Most

Table 3 Number of postoperative visits

No of post-operative visits	No of outpatients	No of inpatients
0	8	8
1	27	27
2	21	16
3	5	6
4	1	2
5	2	4
6	2	2

There are no significant differences between the groups ($\chi^2=2.35$, $df=5$, $P>50$ per cent)

essentially the end result in the two groups is the same.

When treating patients with meniscus injuries with outpatient surgery the crucial point is to secure a safe and relevant after-treatment. In our opinion this can be done only by a careful verbal and written communication which entails that the patient achieves a true understanding of what the lesion and the surgery is about and most important of all how he is to perform relevant training of his knee extensors without provoking an undue synovial irritation of the knee joint.

All those who are to be operated on as outpatients should have the clinical diagnosis confirmed as an isolated meniscus injury, without concomitant lesions in the crucial ligaments. Usually these combined lesions produce instability symptoms and in such cases more detailed evaluation, either arthrography or arthroscopy, is needed. The most benign and symptomless cases of anterior cruciate rupture found in the present series obviously do not need surgical treatment.

The study shows that a considerable number of the patients need some help at home during the first days after the operation. It is therefore advisable to operate on as outpatients those who live alone and lack immediate help from another person.

The advantage of meniscus operation as an outpatient procedure is perhaps the release of expensive nursing resources for others who require more nursing care. Annually around

150 patients are operated for meniscus lesions at our clinic. Of these, almost half are operated as outpatients, i.e., about 225 to 300 bed-days are released for other groups of patients. If we consider the patient's social situation, that is to say, whether or not he lives alone, we think that without increased discomfort for the patient and without increased medical risks it is possible to operate on a large group of patients with meniscus injury as outpatients.

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IMMEDIATE EFFECTS OF MENISCECTOMY ON THE KNEE JOINT

The Effects of Tensile Load on Knee Joint Ligaments in Dogs

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Tensile strength variables for the collateral ligaments were compared after excision of the meniscus in one knee, the corresponding meniscus in the contralateral knee of the same dog being intact. Removal of the meniscus was associated with a three fold increase in the tensile strength of the collateral ligament.

not affected by lateral meniscectomy. It is proposed that tensile loads are distributed more favourably in the medial collateral ligament by the intact medial meniscus with firm capsular attachments than in the "normal" ligament after meniscectomy.

Key words: knee joint, ligament articular, semilunar cartilage, tensile strength

Accepted 22.7.78

Many different functions have been attributed to the menisci of the knee joint. Smilie (1970) maintains that the menisci increase the stability of the joint "by deepening the tibial surface and filling in the dead space". Slocum & Larson (1968) describe rotatory instability of the knee joint, and state that the medial meniscus to some extent blocks this instability by virtue of the posterior horn. Wang & Walker (1974) found experimental evidence of a rotatory stabilizing function of the menisci. Fairbank (1948) also suggested a weight-bearing function. Several

others believe that the stability of the knee joint is impaired after medial meniscectomy (Smilie 1970, Johnson et al 1974, Kennedy et al 1974).

This study was designed to answer the following questions.

- 1 Do the menisci contribute to the stability of the knee joint?
- 2 If so, is the stabilizing effect due only to the volume and form of the menisci, or is it dependent on the close anatomical relationship between the meniscus and collateral ligament on the medial side and is consequently confined to this compartment?
- 3 Is the maximum load uptake of the medial collateral ligament affected by meniscectomy?

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MATERIAL AND METHODS

The study was performed on beagle dogs of average weight 11.7 kg (range 7.7–17.5) and mean age 12 months (range 11–13). They were bred at the same kennels, and were all in good condition at the time of killing. Two different series were studied separately.

Series A Twenty joints from 10 animals were used to compare the tensile strengths of the right and left medial collateral ligaments. Meniscectomy was not done on these joints, which had been frozen before the tests.

Series B (Figure 1) Another series of fresh samples was run to compare the tensile strength of one collateral ligament of one knee with that of the corresponding ligament of the other knee from the same animal, on the one side in the presence of the intact meniscus and on the other after removal of that structure. The groups were selected at random. This series comprised fresh

knee joints from 40 dogs, the tests being carried out within 2–10 hours of killing. During this time all specimens were kept cool. The load-deformation curves were analysed and the results treated statistically by the usual method (Snedecor & Cochran 1967).

Preparation of specimens

After killing, the hind legs were dissected at the hip joints. The femur and tibia were freed from muscles without opening the knee capsule, interfering with ligament structures. The free ends of the femur and tibia were placed in aluminium cylinders. After centring, the bone was fixed in position with Wood's metal type B at 58°C. The

joint and its capsular structures intact.

Before dissection, the angle between the tube in full extension was measured for each specimen to guarantee accurate positioning in the machine. The fibres of the collateral ligament were then identified and dissected free. Identification of the most anterior and most posterior fibres was facilitated by lateral angulation of the joint at different degrees of extension and flexion. Two short incisions were made in the capsule at the anterior and posterior borders of the ligament parallel to the fibres (Figure 2). The purpose of this incision was to facilitate the following dissection after mounting (see below), eliminating accidental injury to the collateral ligament fibres. At this point (in series B) it was announced whether the joint was to be tested with the meniscus intact or excised. Joints with intact

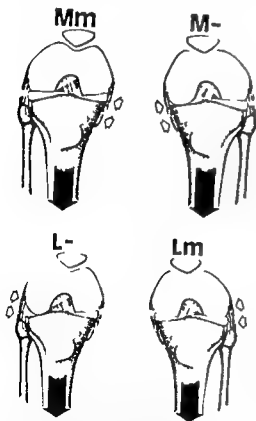


Figure 1 Tensile load applied to the medial or lateral collateral ligament in both knees of the same animal. All other capsular and ligamentous structures divided. The arrows show the direction of the tensile load (lateral) mer application.

Removal of meniscus

An incision was made along the periphery of the meniscus starting at the anterior end of the cartilage, with the knee flexed 90°. When the anterior and middle third had been separated from the capsule the meniscus was divided transversely (Figure 3) and the detached segment taken out. The posterior horn was thus left in place together with the intact posterior capsule, the collateral ligaments, and the cruciates while the specimen was being mounted in the machine. These intact ligaments guaranteed correct anatomical positioning of the joint. When the preparation had been rigidly mounted the cruciates, the posterior capsule and the collateral ligament not being

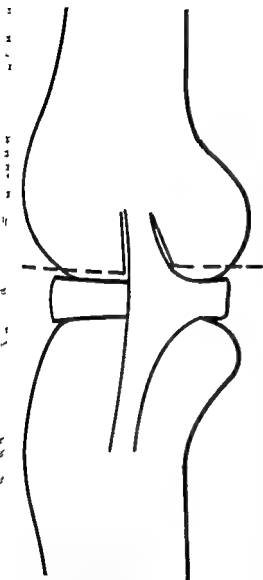


Figure 2 Incisions parallel to fibres of the collateral ligaments before mounting (—) and before excision of meniscus Incisions made after mounting (---)

tested were divided. With the posterior capsule wide open the posterior horn could then easily be cut out with the scalpel under full view. The entire meniscus could thus be excised without risk of damage to the ligament to be tested.

Equipment

A material testing system (MTS 5 Mp, MTS Corporation, Minneapolis, Minnesota, USA) with

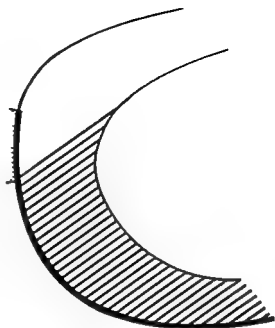


Figure 3 ■ Meniscus segment excised before mounting (M-, L-) (—) Meniscus and its attachment to the capsule divided □ Segment removed after mounting, before test

an error of ± 1 per cent of the recorded load was used. All tests were carried out at a deformation rate of 15 mm/s. The deformation of the test structures was recorded with an inductive transducer built into the movable piston of the machine. The load was registered as a function of the deformation on a Bryans 26000 xy-recorder (Bryans Southern Instruments Ltd, Mitcham, Surrey, England).

Symbols and definitions

Maximum load — maximum tensile load corrected for body weight (P_{\max} , N/kg bw, Figure 4)

Elasticity angle — the angle between the linear part of the curve and the horizontal axis (α , °)

Laxity — the distance on the load deformation diagram from zero to the point extrapolated from the linear part of the curve on the x-axis (δ_0 , mm)

Elongation — the elastic and plastic phase of deformation projected on the x-axis (δ , mm)

Total elongation — the sum of laxity and elongation phase (mm)

Ligament — condyle distance — the distance from the tested ligament to the midpoint of the femorotibial contact area on the contralateral tibial condyle (VFTC) (c, mm)

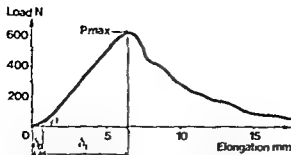


Figure 4 Characteristic load-deformation diagram for a ligament, showing three phases the initial laxity (the "toe"), the second phase of elastic deformation, and the third phase of plastic deformation.

Laxity angle — the approximate angle (β) corresponding to the laxity phase when the vertical deformation movement is theoretically converted into an angulation in the transversal plane with an axis through MFTC. $Tg \beta = \frac{\delta_2}{c}$

Rupture angle — the approximate angle (γ) corresponding to the total elongation of the ligament when the vertical deformation is theoretically converted into a transverse angulation with an axis through MFTC. $Tg \gamma = \frac{\delta_2 + \delta_3}{c}$

RESULTS

Series A (n=20) The twenty controls showed a coefficient of variation between right and left legs of ± 5.4 per cent with regard to maximum load at rupture of the medial collateral ligaments. The difference between right and left was not significant. Concerning laxity, the difference between right and left was not statistically significant, but elongation was significantly less on the right side than on the left ($P < 0.02$). Small unexpected aberrations in the linear part of the curve were seen more often for the left ligament than for the right (Figure 5)

Series B (n=80) The following results were obtained. Table 1 shows the laxity of the medial collateral ligament. With the meniscus intact the values were higher at 30° flexion than with the knee extended ($P < 0.02$). After excision of the meniscus (Group M-) the

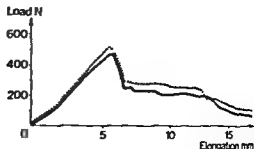


Figure 5 Load-deformation diagram of right (—) and left (- -) medial collateral ligaments from the same animal. An aberration is seen in the curve for the left ligament before breaking point. Apart from this there is close agreement between the two sides before the rupture. The diagram also shows that continuity of the ligament is lost at a late stage and at great deformation.

values were still higher, both in extension ($P < 0.001$) and 30° flexion ($P < 0.02$). The corresponding values for the lateral collateral ligament (Table 2) were also significantly higher ($P < 0.001$) after excision of the lateral

Table 1 The laxity (δ_0 , mm) of the medial collateral ligament with intact (Im) and extirpated (M-) medial meniscus in different positions of the knee joint (mean \pm s.e.m.). All structures but the test ligament were divided in four dogs before fixation in the test machine and these figures were therefore excluded from the part of the study

Test position	Medial meniscus	
	intact (Im)	extirpated (M-)
extension (n=11)	0.26 \pm 0.17	0.75 \pm 0.29 $P < 0.001$
flexion 30° (n=14)	0.50 \pm 0.28	0.75 \pm 0.25 $P < 0.01$
	$P < 0.02$	n.s.

Table 2 The laxity (δ_0 , mm) of the lateral collateral ligament with intact (Lm) and extirpated lateral meniscus (L-). All tests were carried out on the extended joint.

Test position	Lateral meniscus	
	intact (Lm)	extirpated (L-)
extension (n=11)	0.31 \pm 0.19	0.54 \pm 0.21 $P < 0.001$

Table 3 The maximum load (P_{max} N/kg body weight) for the medial (Mm, M- resp) and lateral (Lm, L- resp) collateral ligaments with intact and with extirpated meniscus

Tested ligament	Meniscus		
	intact	extirpated	
Medial coll. lg ($n=29$)	44.1 \pm 10.7	38.8 \pm 9.8	$P < 0.001$
Lateral coll. lg ($n=11$)	43.7 \pm 6.8	43.9 \pm 9.1	n.s.

meniscus (Group L-) The laxity in Group M- was, however, significantly higher than in Group L- when tested in the same position ($P < 0.05$). There was no significant difference in elongation of the collateral ligament between groups Mm and M- and Lm and L-, respectively (means for the medial collateral ligament 5.01 \pm 0.80 in extension and 5.59 \pm 0.68 in 30° flexion).

The Young modulus of elasticity for collagenous structures was not calculated owing to lack of precise methods for studying the cross-sectional area of the ligament (Ellis 1969).

The values for maximum load were lower after medial meniscectomy (see Table 3). The tests on the medial collateral ligament with intact meniscus showed a mean load at rupture of 44.1 \pm 10.7 N/kg body weight, whereas the other knees from the same dogs showed a mean load at rupture of only 38.8 \pm 9.8 N/kg body weight after excision of the medial meniscus. This difference is highly significant ($P < 0.001$). Excision of the lateral meniscus caused no significant change in tensile strength of the lateral collateral ligament.

With the approximation that transverse angulation of the tibia occurs about an axis through the midpoint of the tibial condylar surface when this is under compression and not subject to sliding and rotation, the laxity and rupture angles were calculated from the following formulae

$$\text{Tg } \beta = \frac{\delta_0}{c} \text{ and } \text{Tg } \gamma = \frac{\delta_0 + \delta_1}{c}$$

The mean laxity angle increased in both groups after medial meniscectomy from 0.7°

to 2.1°, and after lateral meniscectomy from 0.7° to 1.2°, when tested under extension. The rupture angle showed no significant change after meniscectomy (medial mean 15.9°, and lateral mean 13.3°).

Localization of tear in ligament

Nearly 80 per cent of the tears on the medial side took place 1/2–1 cm below the condylar surface of the tibia, that is, where deep fibres of the ligament are inserted and the superficial fibres ride over the convex part of the tibial surface. The other 20 per cent were situated at the proximal and distal insertions of the ligament. Groups Mm and M- showed no observable difference concerning type or localization of the tear. The lateral tears revealed a weak point just at the fibular insertion of the ligament, where most tears occurred.

DISCUSSION

For practical and ethical reasons it is often impossible to obtain suitable human material. Many biomechanical investigations have therefore been done on tendon and ligament preparations from rats, rabbits, cats, dogs, monkeys and other species (Smith 1954, Vudik & Lewin 1966, Matthews & Ellis 1968, Haut & Little 1969, Gupts et al. 1971, Welsh et al. 1971 and Noyes et al. 1974). The gross morphology of the knee joint with regard to menisci and cruciate and collateral ligaments is essentially similar in man and many breeds of dogs, and like some other researchers (Marshall & Olsson 1971, McDonoghue et al. 1971, Alm et al. 1974) we therefore used dogs for this study. Caution should be exercised, however, when applying these results to human conditions.

The increased laxity of the ligament after removal of a meniscus might suggest that the structure has in some way undergone change. Laxity was increased not only for the medial collateral ligament after medial meniscectomy, however, the lateral collateral ligament

also showed increased laxity after lateral meniscectomy in spite of the known absence of anatomical relations between the meniscus and ligament in this compartment. This means, then, that resection of the anterior and middle two-thirds of the meniscus with all ligaments and practically all capsular structures intact leads to a slight but significant alteration in femoro-tibial orientation, which in turn implies that the menisci are normally under pre-stress when no external tension or compression is applied. Owing to their form and position the menisci will then come under further stress when the joint is compressed by weight-bearing. These changes in the initial part of the tension-load-deformation curve therefore corroborate the theory that the menisci have a weight-bearing function. Preliminary studies on load-deformation due to compression forces in human knee joints before and after meniscectomy have been published by Seedom et al (1974), who found the part played by the meniscus in weight-bearing to be about 50 per cent. Using pressure transducers on cadaver knees Walker & Erkman (1975) also found the menisci to take up at least 50 per cent of the total load through the joint, more being taken up on the lateral side than the medial. Apart from the finding of normal meniscus pre-stress we are unable on the basis of our present findings to assess further the contribution of the menisci in weight-bearing. The pre-stress of the menisci reflected by our figures for laxity seems to vary with flexion and extension. Walker & Hajek (1972) studied the part played by the menisci in the contact stress on the central areas of the articular cartilage, and found reduction in contact stress especially at the extremes of motion. Our results correspond with this. However, laxity and pre-stress are affected by the mutual relations of the joint mechanics and ligament insertions in different positions of the joint.

As we have shown, meniscectomy may also lead to a three-fold increase in transverse angulation. An initial laxity of 2° might seem too small to be of any importance.

Nevertheless, in a study on weight transmission through the human knee joint Kostuk et al. (1975) found that a lateral angulation of 3° in either direction completely disburdened the opposite condyle. Consequently, this apparently minor change after meniscectomy may have far-reaching mechanical consequences for the joint. Furthermore, experimentally induced instability of the knee joint in dogs is known to promote degenerative changes (Marshall & Olsson 1971, O'Donoghue et al. 1971), and such changes are seen also in man (Salter 1970). The increased laxity and alteration in femoro-tibial orientation we have found may help to explain the high incidence of degenerative changes in the human knee joint cartilage (Fairbank 1948, Tapper & Hoover 1969, Dandy & Jackson 1975) after meniscectomy.

The increase in laxity was greater after excision of the medial than the lateral meniscus, suggesting that factors other than mere loss of meniscus volume may be in operation on the medial side. Meniscectomy may possibly lead to unavoidable disturbance of the intimate relationship between the meniscus and the medial ligament complex. Surprisingly, the leaving behind of a small rim of meniscus in a few cases did not seem to influence the result. The effects of this anatomical relationship on the tensile properties of the ligament have not been investigated in man.

The maximum tensile strength also differed on the medial and lateral sides. As expected, meniscectomy did not affect the tensile properties of the lateral collateral ligament, but the maximum tensile strength of the medial ligament diminished by 12 per cent. A corresponding reduction in elongation might have been expected, but this was not significant. The tear not at the level of the excised meniscus; stally, however, the rim remained intact than would be reduced after. Furthermore, at the same

meniscectomy Hypothetically, the stress over the tibial area, where most of the ruptures occurred, would appear to be better distributed under physiological conditions by the intact bonds between the medial meniscus and the ligament than after meniscectomy

The strength of the medial collateral ligament in dogs has also been studied by Tipton et al (1970) If their figures for separation force are corrected for mean body weight, the ligament in the trained group of dogs showed a mean strength of only 270 N/kg body weight, that is, much lower than in this study The material differed, however, and furthermore the deformation rate was only 0.25 mm/s Collagenous tissue shows a strain rate sensitivity At high rates of deformation, tissue elasticity is changed, collagenous tissue tolerates a greater load before rupture, and the incidence of ligamentous tears will exceed the incidence of bone avulsion (Noyes et al 1974) Our findings consequently seem more physiological

Elongation was the only factor that showed a significant difference between right and left This is not accompanied by a significant change in stiffness ($\tan \alpha$) between the compared ligaments, however The difference seemed instead to be due to small aberrations in the curve, commoner in the left-side preparations than in the right It cannot be determined whether these changes in deformation of the bone-ligament-bone preparation occur within the ligament substance or at the insertions. It seems quite possible that the aberrations could represent tears of isolated fibre bundles before ligament failure occurs, and in fact such microscopical breaches preceding ultimate disruption have been described (Noyes et al 1974) Differences in tensile properties and elasticity of bone-ligament bone preparations between trained and untrained limbs have also been reported (Vudik 1968, Laros et al 1971) Vudik (1968) felt that qualitative changes must take place within the ligamentous tissues owing to differences in the load-relaxation phenomenon Our findings may

indicate that there is some qualitative difference in the medial collateral ligaments on the dominant and non-dominant sides.

Summary and conclusions

The knee joint of beagle dogs, which bears essential similarities to the human knee joint, showed the following changes after excision of the medial or lateral meniscus.

- 1 Removal of a medial or lateral meniscus leads to a small but significant change in the laxity of the joint The results indicate that the menisci are normally under pre-stress.
- 2 The increase in laxity angle is nearly two-fold after removal of the lateral meniscus and three-fold after removal of the medial the greater increase after medial meniscectomy possibly being due to disturbance of the intimate anatomical relationship between the medial meniscus and the deep capsular fibres of the medial collateral ligament
- 3 The medial collateral ligament shows a reduction of load at failure of more than 10 per cent immediately after meniscectomy
- 4 The results accord with previous compression load investigations, indicating that the meniscus may have a load-bearing function With this experimental model, however, the magnitude of this function cannot be studied

ACKNOWLEDGEMENT

The authors wish to extend their thanks to the staff of the Toxicological Laboratory ASTRA AB, Södertälje Sweden who kindly supplied us with specimens. Financial support was provided by the Swedish Medical Research Council (Projekt nr 17X 3916 17X-645).

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EFFECT OF PNEUMATIC TOURNIQUET ON MUSCLE OXYGEN TENSION

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Recent investigations suggest that circulation in a limb can be reduced with a tourniquet to less than 1 per cent of the control limb, or even completely occluded. The development of tissue oxygen tonometry with implanted silastic tubes has provided new possibilities for assessing muscle tissue oxygen tension. In the present work, this method was employed to register the effect of tourniquet blockade on the lower limb muscle PO_2 in rabbits. The duration of tourniquet blockade was 60, 120 and 180 minutes. The baseline muscle PO_2 in the tibialis anterior muscle was 22.6 ± 0.6 mmHg. During the tourniquet blockade the oxygen tension dropped to minimal values between 9.2 ± 0.5 and 10.7 ± 0.6 mmHg in these experimental groups, but the tissue microclimate never reached fully anoxic conditions. The rapid response of muscle PO_2 to oxygen breathing after release of the blockade suggests that limb microcirculation tolerates tourniquet occlusion well.

Key words: pneumatic tourniquet, tissue PO_2 , silastic tonometer

Accepted 31 III.78

The clinical advantages of a pneumatic tourniquet are well known, since surgery in a bloodless field has been practised for over a century (Esmarch 1873). However, maintaining tourniquet blockade involves disadvantages, the greatest of which is probably tissue ischaemia.

Recent investigations suggest that circulation in a limb can be reduced with a tourniquet to less than 1 per cent of the control limb (Klenerman & Crawley 1977). The resistance of the microcirculation of striated muscle against ischaemia is largely unknown. In recent studies the role of tissue oxygenation in operative procedures has been emphasized (Kivisaari & Niinikoski 1975, Niinikoski 1977).

The development of tissue oxygen

tonometry with implanted silastic tubes (Niinikoski & Hunt 1972) has provided new possibilities for investigating muscle tissue oxygen tension. In the present work, this method was employed to register the effect of tourniquet blockade on the lower limb muscle PO_2 in rabbits.

MATERIAL AND METHODS

Seventeen rabbits of both sexes, weight 3.0-3.9 kg, were used in this study. Anaesthesia was induced with intravenous sodium pentobarbital, and maintained by continuous infusion. A Holter® Atrial Catheter J, A 190, Extracorporeal

Medical Specialties Inc., Millis, Mass., USA) was implanted in the tibialis anterior muscle (Figure 1). The implantation was made through a wide-bore needle. The tube ends were left outside the skin after closure and fixed with a silk ligature. A length of 14 to 15 cm remained inside the muscle tissue. Three days later the rabbit was again anaesthetized and muscle oxygen tension

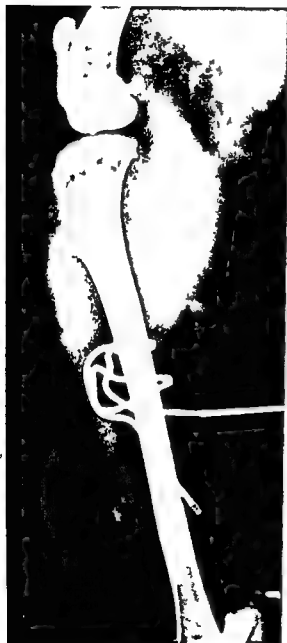
was determined according to Nunniköski & Hunt (1972). The silastic tonometer was perfused continuously with hypoxic saline PO_2 3 to 8 mmHg with a slow injection pump (Model 1100 Harvard Apparatus Co Inc., Millis, Mass. USA), and tissue PO_2 was measured from the efflux in the Radiometer gas monitor coupled with a Servogor² chart recorder (Goerz Electro GmbH Vienna, Austria). Oxygen impermeable nylon catheters were used as connector tubes in the perfusion system. The response of different durations of tourniquet blockade was measured. Five rabbits had 60-minute tourniquet ischaemia and in five animals ischaemia lasted for 120 or 180 minutes, respectively. The tourniquet ischaemia was maintained by means of a 6 cm broad, Riva-Rocci type cuff around the upper part of the leg. The cuff was inflated to 300 mmHg. In each animal the response of the muscle oxygen tension to the release of tourniquet and to breathing of pure oxygen was also registered. In two cases the tourniquet blockade lasted 30 minutes and breathing of pure oxygen was continued throughout the whole experiment.

RESULTS

The baseline PO_2 before the application of the pneumatic tourniquet ranged between 18 and 26 mmHg (mean and SEM 22.6 ± 0.6 mmHg). Breathing of pure oxygen for a period of 15 minutes increased the level of intramuscular PO_2 to 90–130 mmHg.

During 60 minutes of tourniquet ischaemia the intramuscular PO_2 declined from the baseline value of 22.2 ± 1.2 mmHg to a minimal value of 9.3 ± 0.6 mmHg within 20–24 minutes (Figure 2a). After release of the tourniquet the PO_2 reached a stable value of 17.8 ± 0.8 mmHg in 5 to 10 minutes and then remained unchanged during the following 30 minutes. When the PO_2 had been stabilized, the rabbits were exposed to pure oxygen through a head tent. This resulted in an intramuscular PO_2 of 85–130 mmHg within 15 to 20 minutes.

During 120 minutes of tourniquet ischaemia the PO_2 declined from the baseline value of 23.7 ± 1.1 mmHg to a minimal value of 10.7 ± 0.6 mmHg within 22 to 28 minutes (Figure 2b). In 5 to 10 minutes after release of the tourniquet, the PO_2 reached a stable level



of 19.5 ± 0.8 mmHg. The intramuscular PO_2 responded in all cases to oxygen breathing with an increase to 80–120 mmHg.

During 180 minutes of tourniquet ischaemia the PO_2 declined from the baseline value of 21.7 ± 1.1 mmHg to a minimal value of 9.2 ± 0.5 mmHg within 19–26 minutes (Figure 2c). After releasing the tourniquet, the

PO_2 reached a stable level of 17.0 ± 0.5 mmHg in 10–17 minutes. The response to pure oxygen breathing was an increase of the intramuscular PO_2 to 90–115 mmHg.

When pure oxygen breathing was continued throughout the experiment, a decline of the PO_2 from 120 mmHg to 11 mmHg was registered (Figure 3).

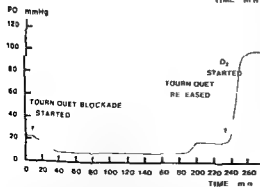
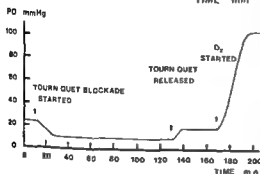
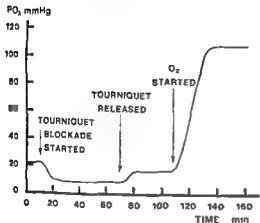


Figure 2 (a) Effect of 60 minute tourniquet blockade on muscle PO_2 , (b) Effect of 120-minute tourniquet blockade on muscle PO_2 , (c) Effect of 180-minute blockade on muscle PO_2 .

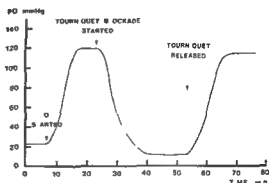


Figure 3 Effect of pure oxygen breathing continued throughout the experiment. A decline of the PO_2 from 120 mmHg to 11 mmHg was registered.

DISCUSSION

The silastic tonometer method of measuring tissue oxygen tension is already well established and has showed its usefulness in several studies. Nunikoski et al. (1972) showed that the silastic tube induces a minimal foreign body reaction.

Kivisaari & Nunikoski (1973) concluded that one of the main problems involved in measuring tissue gases by means of micro-electrodes is the wide topographical variation of the PO_2 readings that normally occurs (Silver 1969). The advantage of the silastic tonometer is that it measures the average extracellular tissue PO_2 (Nunikoski & Hunt 1972).

In earlier investigations the silastic tonometer has been used extensively in several tissues, such as human subcutaneous tissue (Nunikoski et al. 1972, Kivisaari & Nunikoski 1973, Heppenstall et al. 1974), human muscle (Cooke et al. 1974), intestinal

wall and peritoneal cavity in animals (Inberg et al 1974, Klossner et al 1974), canine lung (Havia & Nunikoski 1976) and canine heart (Havia & Nunikoski 1977)

The reported mean baseline PO_2 values have varied in most tissues between 20 and 30 mmHg. In rabbit subcutaneous tissue PO_2 varied between 20 and 25 mmHg (Nunikoski & Hunt 1972). Canine myocardium PO_2 ranged from as low as 8 to 40 mmHg with a mean of 22 mmHg.

The baseline muscle PO_2 ranged in our study from 18 to 26 mmHg. This is compatible with the tissue oxygen tensions reported in other studies.

In the present study, the application of tourniquet always produced a decline in the intramuscular oxygen tension. The minimal value of 9–11 mmHg was achieved in 19–26 minutes and then remained constant during the rest of the tourniquet time, but never reached zero. In accordance with the present findings, Nunikoski et al (1972) found it puzzling that a 20-minute occlusion of limb circulation did not result in a PO_2 of zero in human subcutaneous tissue. In the investigation of Kivisaari & Nunikoski (1975) the intraosseous PO_2 fell abruptly after circulatory arrest so that most of the decrease occurred within 2 minutes, but also in this case the PO_2 never reached zero. Furthermore, the release of circulation resulted momentarily in a PO_2 slightly above the normal level, probably due to reactive hyperaemia (Nunikoski et al 1972, Kivisaari & Nunikoski 1975). In the present study, the muscle PO_2 remained slightly under the normal level after releasing the blockade. However, after a few minutes of pure oxygen breathing the PO_2 increased sharply. This indicates that the microcirculation even after 3 hours of tourniquet blockade was functioning well.

Continuous oxygen breathing during the tourniquet experiment had no influence on the decrease of the PO_2 and the minimal value was compatible with the one achieved with room air breathing. This has been interpreted as total occlusion of the circulation

caused by the tourniquet. The decline of PO_2 and recovery after tourniquet release seemed to be independent of tourniquet time.

It can be concluded that inducing a total blockade of local circulation in an extremity produces a profound fall of the muscle PO_2 , but the tissue microclimate never reaches fully anoxic conditions. The rapid response of muscle PO_2 to oxygen breathing after release of the blockade suggests that tissue oxygenation is rapidly restored after tourniquet release.

ACKNOWLEDGEMENTS

This work was supported by the Emil Aaltonen Foundation and Paulo Foundation. The authors wish to thank Mrs. Paivi Pennanen and Mrs. Ingrid Lautenschlager for skilful technical assistance.

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THE INFLUENCE OF THE DEEP FEMORAL ARTERY ON WOUND HEALING IN AMPUTEES

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Seventeen patients with arterial occlusive disease, of whom 14 were diabetics, were studied by angiography after amputation of the lower extremity. In one patient the superficial femoral artery was normal and the deep femoral

alone was occluded and wound healing was normal and in nine patients both the superficial and deep femoral arteries were occluded and wound healing was delayed.

Wound healing of the stump after amputation of the lower extremity due to extensive arterial occlusive disease is decided by the patency of the deep femoral artery.

Key words: amputation, angiography, arterial occlusive disease, deep femoral artery, superficial femoral artery, wound healing.

Accepted 28 III 78

Level of amputation and quality of wound healing are of crucial importance in the rehabilitation of patients after amputation of the lower extremity for arterial occlusive disease. Angiography is one of the tools used to determine the proper level of amputation (Baddeley & Fulford 1964). A successful amputation is considered one at "the lowest site with considerable chance of healing" (Browse 1973). It is important to determine the correlation between the angiographic findings and wound healing after amputation

6 weeks) were also investigated for comparison. All patients gave informed consent. The age range was 60-89 years, all but one were men. Fourteen were overt diabetics.

The vessels investigated were:

- 1 The trunk consisting of the common iliac, external iliac and common femoral arteries
- 2 Superficial femoral artery
- 3 Deep femoral artery

Occlusion was graded as: Absent or mild when

two of the authors without knowledge of the patients' clinical findings. Angiography was performed by Seldinger's technique (1953).

PATIENTS AND METHODS

Angiographic investigations were carried out on 11 patients with lower extremity amputation for arterial occlusive disease, in whom the wound took more than 11 weeks to heal. Six amputees with a normal rate of wound healing (within

RESULTS

Figure 1 represents a case where the whole arterial trunk of the lower limb is patent. In Figure 2 the superficial femoral artery is com-

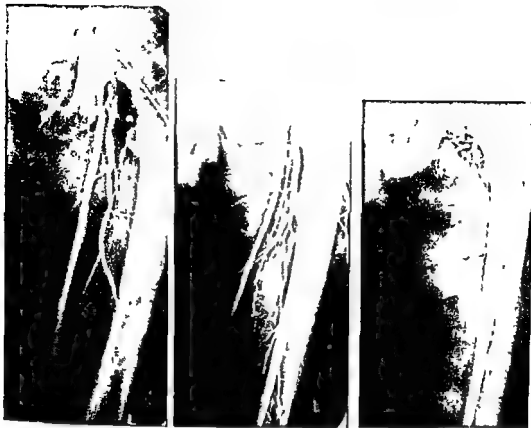


Figure 1 Arteriography showing patent superficial and deep femoral arteries. Figure 2 Arteriography showing occlusion of the superficial femoral artery and patent deep femoral artery. Figure 3 Arteriography showing occlusion of the common femoral artery. There is no filling of the superficial and deep femoral arteries.

pletely occluded. The deep femoral artery is patent and its network of collaterals can be seen. In Figure 3 the main arterial trunk of the lower extremity is completely occluded.

Table 1 presents the relation between rate of wound healing, the level of amputation and the artery occluded. In one case no occlusion was demonstrated. The reason for amputation in this case was occlusion in the arteries of the calf, and a successful below knee amputation was performed.

In two cases none of the arteries of the lower extremity could be demonstrated on angiography. This severe impairment of blood supply caused very prolonged wound healing of the stump (up to a year). In five cases the superficial femoral artery alone was

occluded, and in nine cases both the superficial and the deep femoral arteries were occluded. When only the superficial femoral artery was occluded, wound healing was normal, but when both the superficial and the deep femoral arteries were occluded, wound healing was delayed. There was no difference between the above knee and the below knee amputations.

DISCUSSION

The superficial femoral artery conducts the blood supply for the calf and foot and it is the most frequent site of occlusion in arterial occlusive disease.

Table 1 Site of arterial insufficiency, rate of wound healing and level of amputation

Site of arterial insufficiency	No of patients divided according to rate of wound healing and level of amputation				Total
	Delayed		Normal		
	AK	BK	AK	BK	
None				1	1
Common iliac, external iliac, common femoral, superficial femoral, deep femoral	2				2
Superficial femoral			2	3	5
Superficial femoral, deep femoral	6	3			9
Total	8	3	2	4	17

The deep femoral artery arises from the lateral aspect of the common femoral artery, supplies the thigh (Martin et al 1968) and anastomoses with branches of the popliteal and geniculate arteries (Boileau Grant 1958). It was believed that the deep femoral artery was only rarely affected in peripheral vascular disease. Lindbom (1950) found that it was occluded in 4 out of 108 angiograms performed. In later studies, narrowing at the origin of the deep femoral artery was found in up to 39 per cent (Beales et al 1966) with a higher incidence in diabetics (30.5 per cent) than in non-diabetics (9.5 per cent) (Haimovici 1967, Tingaud et al 1974). These findings are in agreement with those of our study and previous studies in Israel, all of which included a high proportion of diabetics (Gaspar 1968, Najenson & Levy 1972).

In the above-mentioned reports, as in the present study, occlusion of the deep femoral artery was part of an extensive arterial occlusive pattern and not an isolated lesion. Healing after amputation was delayed when both the superficial and deep femoral arteries were occluded, but it was normal when the deep femoral artery was patent.

It is our conclusion that the postoperative

patency of the deep femoral artery is a major factor in the prognosis of an amputation at any level. In the presence of superficial femoral artery occlusion, the patency of the deep femoral artery decides the outcome of a below knee amputation as a source of action as the collaterals to the an artery of supply it also knee

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Table 1 Site of arterial insufficiency, rate of wound healing and level of amputation

Site of arterial insufficiency	No. of patients divided according to rate of wound healing and level of amputation				Total
	Delayed		Normal		
	AK	BK	AK	BK	
None				1	1
Common iliac, external iliac, common femoral superficial femoral deep femoral	2				2
Superficial femoral			2	3	5
Superficial femoral deep femoral	1	3			4
Total	3	3	2	4	12

The deep femoral artery arises from the lateral aspect of the common femoral artery, supplies the thigh (Martin et al. 1968) and anastomoses with branches of the popliteal and geniculate arteries (Boileau Grant 1958). It was believed that the deep femoral artery was only rarely affected in peripheral vascular disease. Lundbom (1950) found that it was occluded in 4 out of 108 angiograms performed. In later studies, narrowing at the origin of the deep femoral artery was found in up to 39 per cent (Beales et al. 1971) with a higher incidence in diabetics (30.5 per cent) than in non-diabetics (9.5 per cent) (Haimovici 1967, Tingaud et al. 1974). These findings are in agreement with those of our study and previous studies in Israel, all of which included a high proportion of diabetics (Gaspar 1968, Najenson & Levy 1972).

In the above-mentioned reports, as in the present study, occlusion of the deep femoral artery was part of an extensive arterial occlusive pattern and not an isolated lesion. Healing after amputation was delayed when both the superficial and deep femoral arteries were occluded, but it was normal when the deep femoral artery was patent.

It is our conclusion that the postoperative

patency of the deep femoral artery is a major factor in the prognosis of an amputation at any level. In the presence of superficial femoral artery occlusion, the patency of the deep femoral artery decides the outcome of a below knee amputation as it is the source of the collaterals to the calf and by its action as an artery of supply to the thigh, it also decides the prognosis of an above knee amputation.

The role and importance of the deep femoral artery have been recognized by several surgeons (Martin et al. 1968, Okike & Bernatz 1976) who have used it for revascularization of the lower extremity when other procedures are not possible.

When an amputation wound fails to heal it is worthwhile performing an arteriography. If the superficial femoral artery is found to be occluded the deep femoral artery should be studied with special care.

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MATERIAL AND METHODS

The material consisted of 62 full-grown rabbits with roentgenologically closed epiphyseal lines in the femur and the tibia. The animals were

groups according to the operation performed (Table 1).

Group 1 (40 animals) All cartilage in the patella groove of the femur in the right knee joint was excised, care being taken not to traumatize the subchondral bone. In the left knee joint, used as a control, only arthrotomy was done. After the operation, the incisions were closed by supramide sutures in the capsule and the skin.

Group 2 (10 animals) The right and the left knee joints were treated in the same way as the right knee of the animals of group 1, i.e., by total excision of the cartilage in the patella groove of the femur. The difference between the two operated knee joints lay in the different times elapsing between operation and sacrifice.

Group 3 (12 animals) All cartilage in the intercondylar groove in the right knee joints was

excised. In the left knee joints one third of the cartilage in the groove was excised.

The sutures were removed 1 week after the operation, except for the animals sacrificed 2, 4 and 5 days after the operation, where the sutures were left intact. None of the animals showed signs of effusion, and the animals were able to use their operated legs on the day after the operation.

^3H thymidine was injected intra-articularly in both joints 30 and 6 hours before sacrifice. All animals were killed by an i.v. overdose of Nembutal[®] (Abbott). Immediately after death, articular cartilage from the tibial condyles and from the lateral femoral condyle of both knee joints was dissected in separate portions, care being taken to avoid the inclusion of subchondral bone and other tissues. The material was weighed

precipitate was washed three times, each time with 5 ml of TCA. The insoluble residue was treated with 5 ml of 0.3 M potassium hydroxide for 18 hours at 37°C to hydrolyze RNA, which was thereby brought into solution. The solution was adjusted to pH 7 by the addition of 70 per cent perchloric acid. Five ml of 5 per cent TCA

Table 1 Summary of the operations performed on the 62 rabbits and the days of sacrifice

		Operation performed	Days postoperatively*					
			2 days	4 days	5 days	8 days	10 days	14 days
Group 1 40 animals	Right knee joint	Excision of all cartilage of the patellar groove of the femur	10		10		10	10
	Left knee joint	Arthrotomy	10		10		10	10
Group 2 10 animals	Right knee joint	Excision of all cartilage of the patellar groove of the femur				10		
	Left knee joint	"		10				
Group 3 12 animals	Right knee joint	Excision of all cartilage of the patellar groove of the femur						12
	Left knee joint	Excision of $\frac{1}{3}$ of the cartilage of the patellar groove of the femur						12

* The figures in the Table refer to the number of animals sacrificed on the given days.

was added to the neutral solution. This resulted in a precipitation of protein and DNA, which were separated from the solution by centrifugation and washing of the precipitate three times, each time with 5 ml of 5 per cent TCA. RNA and DNA in the separated fractions were determined with the orcinol reaction (Mejbaum 1939) and the Cernotti procedure (Cernotti 1952) respectively. The separation of RNA and DNA was checked in all experiments by applying both reactions to the RNA as well as in the DNA fractions. The patella and the medial femoral condyle were used for histological and autoradiographical examination and were immediately fixed in 10 per cent formalin. With a circular saw the patella was divided in the frontal plane, and the medial femoral condyle in the sagittal and transverse planes. The specimens were then decalcified in formic acid and sodium citrate, embedded in paraffin and cut into sections 5–7 μ thick. The sections were stained with haematoxylin-eosin and according to the van Gieson method. Autoradiographs of routine histological sections were prepared according to the dipping method with Ilford K2 liquid emulsion. After 3 weeks exposure, the autoradiographs were developed in Gevaert X-ray developer G 230 and fixed in Gevaert X-ray fixer Q 305. The sections were stained through the emulsion with Mayer's haematoxylin.

RESULTS

Biochemical study

There were no differences in DNA and RNA concentrations or DNA synthesis between the arthrotomized animals and the animals with joint cartilage partly or totally excised from the patellar groove.

Histological study

Histological examination of the specimens revealed no persistent epiphyseal lines. Well defined "tidemarks" could be seen. In one of the specimens, where the cartilage had been excised from the patellar groove, the calcified cartilage had been damaged. The cartilage was usually excised down to the lower part of the columnar layer.

Control animals. No changes from the normal were seen in the histological examination.

Group 1

Two days after the operation – 10 animals. Proliferation of synovial cells occurred at the joint margins and in one specimen osteoblastic activity was also seen. The joint cartilage in three specimens showed chondrocytes, which appeared swollen in comparison with normal cells. In two of the above-mentioned specimens, small areas of cell necrosis were seen in the transitional and columnar layers of the cartilage. In seven specimens no changes in the cartilage were seen, and there was no osteophyte formation in this group of animals.

Five days after the operation – 10 animals. The degree of cell proliferation at the joint margins was greater than after 2 days in all 10 animals. Osteoblastic proliferation at the joint margins was seen in six animals. In one of the animals, fibrillation was seen down to the "tidemark" in the cartilage of the patella and in the neighbourhood of this fibrillation, cluster formation was seen. The changes were located at the margins of the patella.

Ten days after the operation – 10 animals. Proliferation of synovial cells at the joint margins was conspicuous. At the same site osteoblastic activity could be seen. In three animals, osteophyte formation had started adjacent to the medial collateral ligament. Cluster formation was present in four animals, at the periphery of the patellar cartilage in three and in the femoral condyle in the fourth. Clusters were seen in the superficial and transitional layers. However, no greater signs of degeneration were seen, although sometimes the chondrocytes appeared swollen in comparison with normal cells, and in two of the patellas initial fibrillation was seen.

Fourteen days after the operation – 10 animals. The synovial cell proliferation and the osteoblastic activity were even more pronounced than after 10 days. In one section the osteoblasts were not only seen at the margins

but also subchondrally under the whole joint cartilage. In 11 animals, osteophytes were seen adjacent to the medial collateral ligament. Degenerative changes of the cartilage were not pronounced but in three animals chondrocytes appeared to be swollen, and in two animals fibrillation and flaking as well as local necrosis of the chondrocytes were seen in the patella sections.

Group 2

These 10 animals presented changes similar to those seen in *group 1* as regards proliferation of synovial cells and osteoblastic activity. No degenerative changes of the cartilage were seen and osteophytes were absent.

Group 3

The 12 animals in this group presented changes in their right knee joints similar to those seen in *group 1* 14 days postoperatively, i.e. peripheral proliferation of synovial cells and osteoblastic cell activity. In one of the 12 animals fibrillation in the patella was suspected, and in three animals cluster formation in the superficial and transitional layers was present. In the operated left knee joint only slight changes, consisting of synovial and osteoblastic proliferation, could be seen.

Autoradiographic findings

Group 1 - 10 animals Several autoradiograms (range 5-16) of each knee joint were studied. Labelled chondrocytes were occasionally seen in 8 out of 39 control knee joints (1 control was lost). The number of labelled cells ranged from 1 to 11. The section showing 11 labelled cells presented histologically a "tumour-like" growth of the cartilage, all the labelled cells being located in this formation. In the right knee joints, labelled chondrocytes were seen in two animals 2 days after the operation, in six animals 5 days after the operation, in eight

animals 10 days after the operation, and in eight animals 14 days after the operation. The labelled chondrocytes were seen in the patella as well as in the femur, and they were not only present around the operative defects of the cartilage. The labelled chondrocytes were usually situated in the superficial and transitional layers whereas occasionally labelled cells were present in the columnar layer.

Group 2 - 10 animals Four animals showed labelled chondrocytes 4 days after the operation, and six animals showed labelling 8 days after the operation. In only one of the left knee joints did the number of chondrocytes exceed that of the right knee joints.

Group 3 - 12 animals Eight animals showed labelling in the right knee joint and eight in the left knee joint. No tendency towards a greater number of labelled chondrocytes was seen in the right knee joints, which had the more extensive operation.

In summarizing the autoradiographic findings, the following results are obtained, expressed in terms of labelled cells in relation to the number of histological sections

2 days	index	0 07
4 "	"	0 1
5 "	"	0 3
8 "	"	0 24
10 "	"	0 8
14 "	"	1 1

DISCUSSION

With the formation of a well-defined zone of calcified cartilage, the chondrocytes cease to divide. Mitotic figures have never been demonstrated in normal adult joint cartilage (Elliot 1936, Crelin & Southwick 1960, 1964, Mankin 1963, 1964, 1968, Telhag 1972). When degenerative changes appear the chondrocytes recover their ability to divide (Hulth et al. 1972) and the proliferation of chondrocytes can be estimated through the increased formation of DNA. At the same

time the synthesis of RNA diminishes (Gudmundson & Telhag 1972). In an earlier investigation it was shown that sham operations on knee joints do not result in mitosis of the chondrocytes (Telhag 1972).

The presence of specific growth-inhibiting factors, "chalones", in tissues other than cartilage has been demonstrated by many investigators (Finegold 1965, Bullough & Laurence 1960, Moorhead et al 1969, Hennings et al 1969, Lasalvia et al 1970, Houck & Hennings 1973). In an earlier investigation (Havdrup et al 1975), it was shown that scattered mitosis of chondrocytes appeared in adult joint cartilage after localized traumatization.

In the present investigation, it was not possible to demonstrate any changes in the biochemistry of the cartilage either in relation to the time elapsing after the operation or in relation to the degree of trauma. This perhaps may be explained by the fact that the number of labelled chondrocytes is very low in relation to the total number of chondrocytes, and that the changes in the metabolism do not result in detectable changes in chemistry.

Fairly abundant numbers of labelled chondrocytes were seen scattered in the right knee joints of the animals in group 1 and in both knee joints of the animals in groups 2 and 3. The number of ^3H -thymidine labelled chondrocytes showed a rising tendency up to 14 days postoperatively. No peak value of mitosis was seen. With increasing time postoperatively, the signs of synovial cell proliferation, osteoblastic activity and degeneration of cartilage developed slightly, but nothing is known about the eventual progress of the changes to manifest osteoarthritis. In the present study, it was not possible to detect any difference between a smaller and a larger trauma in relation to the number of ^3H -thymidine labelled cells.

In a paper concerning scattered mitosis of adult joint cartilage after a localized trauma, Havdrup et al (1975) showed that labelled chondrocytes could be seen in the sham operated knee joints. In the present investiga-

tion, 8 out of 39 control knee joints in group 1 showed chondrocytes labelled by ^3H -thymidine. As mentioned previously, cell proliferation in other organs is regulated by specific cell inhibitors, i.e., chalones. When for example, liver and kidney (Saetren 1956) skin (Bullough & Laurence 1960, Finegold 1965) and bone marrow (Hulth & Johnell 1976) are damaged the remaining cells start dividing. This is possibly due to a decreasing concentration of chalones. In the present investigation a similar explanation can be given, i.e., by excision of the cartilage the concentration of chalones in the operated knee joint is reduced and consequently the chondrocytes start dividing. Possibly, the ^3H -thymidine labelling of the chondrocytes of the control knee joints is due to a decrease in the concentration of circulating chalones. If this is valid, mitosis of the chondrocytes in other joints should also appear.

The explanation given above cannot be proven at present. However, there is nothing to contradict the theory that chalones regulate the proliferation of chondrocytes. This could explain the initial regeneration of chondrocytes in osteoarthritis.

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TORSIONAL STRENGTH AND GEOMETRY OF DIAPHYSEAL BONE

An Experimental Study on Dogs

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Received 15 June 1977
Accepted 15 June 1978

A previously presented method for measuring the torsional strength of diaphyseal bones has been used to study the effect of direction of twist upon the torsional strength and stiffness of diaphyseal canine bones. No significant effect of the direction of twist upon the studied properties has been found. The reason for the observed twist direction independence of the torsional strength and stiffness is assumed to be the adaptation of the diaphyseal bone architecture to functional demands.

Key words: bone, experimental measurement of bone stiffness, experimental measurement of bone strength, maximum torque capacity, strength properties.

Accepted 8 July 78

The maximum torque capacity is considered a suitable measure of strength of diaphyseal bones (in the following referred to as long bones). Torsion testing has been used by previous investigators to study the strength of long bones themselves or the effect of different treatments upon their strength (Burstein & Frankel 1971, Burstein et al 1972a, Sammarco et al 1971, Uhtoff & Duboc 1971, Mensch et al 1976, Stromberg & Dalén 1976a, b).

Previously, both bones of a pair have, with few exceptions, been twisted either inwardly or outwardly (Sammarco et al 1971,

Stromberg & Dalén 1976), that is, the twist direction with respect to the bone geometry has been the same for both bones and the possible effect of the twist direction upon the torsional strength has been eliminated. Others have not stated the actual twist direction at the tests, obviously assuming this to have no effect upon the torsional strength (Burstein et al 1972a, Mensch et al 1976). Moreover, in the literature no report has been found where the effect of the anatomical asymmetry of bones upon their torsional strength has been studied. From the point of view of strength of materials nothing contradicts the assumption that the torsional strength of an asymmetric body depends upon the direction of twist.

The aim of this study is to elucidate the effect of the anatomical asymmetry of long bones upon their torsional strength and

Financial support was obtained from the Swedish Medical Research Council (Project no. 77-17X-04788-02), and from the Trygg-Hansa Research Fund for Bodily Injury or Personal Accident Insurance.

The effect has been studied by twisting bones of a related pair in different directions with respect to the bone geometry in the torsional tests.

MATERIAL

The test material chosen was 7 related pairs of femurs and 13 pairs of tibiae, with closed epiphyseal lines, from long legged dogs of both sexes and of varying breed. From each related pair of bones, one was selected at random for outward twist and the other for inward twist.

The animals were sacrificed with lethal doses of sodium (Nembutal[®], Abbott Laboratories, USA) administered i.v. Immediately after death the bones were freed of all soft tissue except the periosteum. The bones were wrapped in gauze saturated with physiological saline solution and inserted into plastic bags. After sealing the bags were stored in a freezer at a temperature of -30°C . Prior to testing the bags were put into physiological saline solution at 37°C for 2 hours. Both bones of a related pair were always simultaneously frozen or thawed. The bones were taken from the saline solution only immediately prior to testing. The time interval between the tests of two related bones was in all cases less than 10 minutes.

AL TESTING PROCEDURE

The bones were twisted to fracture in a special fixture for torsional testing of long bones. The stress concentrations in the bones were prevented by using a previously described method of fixation of test bones in the twist machine (Strömberg & Dalén 1976a). During the test the torque-time relationship was plotted on a time recorder (Hewlett Packard 7005 B). The angular velocity of the torsion machine is constant and independent of torque in the test range. The torque-twist curve for a bone is thus readily obtained by calibrating the time axis in degrees of twist. Bone material is visco-elastic, that is, its mechanical properties are time-dependent (Ehman & Byars 1965, Burstein & Frankel 1973, Sammarco et al. 1971, Burstein et al. 1973). Previous studies have shown that the torque capacity and stiffness are in general a function of the angular velocity in the range

3–12 degrees per second (Strömberg & Dalén 1976a). This means that the time-dependence is negligible in the angular velocity range studied. In view of this, the angular velocity was set at 6 degrees per second in the present study. Prior to each test the equipment was calibrated against a known torque, and zero drift of the time base recorder was checked.

The experimental error of the method is less than ~ 3 per cent. This includes the error due to the scatter of the maximum torque capacity of related pairs of diaphyseal bones twisted in the same direction with respect to the bone geometry. Thus the precision of the method is such that any difference larger than ~ 3 per cent between the torsional strength of a test bone and its control is detected inevitably.

RESULTS AND CALCULATIONS

From the torque-twist curve the maximum torque capacity was obtained (Figure 1). The maximum torque capacity is represented by the coordinates of the point on the torque-twist curve corresponding to the onset of ultimate failure of a bone. The first part of the torque-twist curve – from zero up to a critical torque – is linear. The corresponding bone stiffness is expressed as torque per unit twist.

Measurements of twist angle and energy were not studied in this investigation.

The difference in the recorded parameters of related bones was expressed in per cent of the mean value for the pair. The mean value of the difference and the standard deviation for the whole sample of bones were also calculated. The measured values of the inwardly and outwardly twisted samples of long bones were analysed according to the paired *t*-test and the significance determined.

The results are shown in Tables 1 and 2. No significant effect ($P > 0.05$) was found of the direction of twist upon the maximum torque capacity or the stiffness of related bones twisted in opposite directions with respect to the bone geometry. In all bones tested a sudden spiral fracture occurred at the diaphysis.

TORSIONAL STRENGTH AND GEOMETRY OF DIAPHYSEAL BONE

An Experimental Study on Dogs

P. NETZ, K. ERIKSSON & L. STRÖMBERG

A previously presented method for measuring the torsional strength of diaphyseal bones has been used to study the effect of direction of twist upon the torsional strength and stiffness of diaphyseal canine bones. No significant effect of the direction of twist upon the studied properties has been found. The reason for the observed twist direction independence of the torsional strength and stiffness is assumed to be the adaptation of the diaphyseal bone architecture to functional demands.

Key words: bone, experimental measurement of bone stiffness, experimental measurement of bone strength, maximum torque capacity, strength properties.

Accepted 8 III 78

The maximum torque capacity is considered a suitable measure of strength of diaphyseal bones (in the following referred to as long bones). Torsion testing has been used by previous investigators to study the strength of long bones themselves or the effect of different treatments upon their strength (Burstein & Frankel 1971, Burstein et al 1972a, Sammarco et al 1971, Uhtoff & Duboc 1971, Mensch et al 1976, Stromberg & Dalén 1976a, b).

Previously, both bones of a pair have, with few exceptions, been twisted either inwardly or outwardly (Sammarco et al 1971,

Stromberg & Dalén 1976), that is, the twist direction with respect to the bone geometry has been the same for both bones and the possible effect of the twist direction upon the torsional strength has been eliminated. Others have not stated the actual twist direction at the tests, obviously assuming this to have no effect upon the torsional strength (Burstein et al 1972a, Mensch et al 1976). Moreover, in the literature no report has been found where the effect of the anatomical asymmetry of bones upon their torsional strength has been studied. From the point of view of strength of materials nothing contradicts the assumption that the torsional strength of an asymmetric body depends upon the direction of twist.

The aim of this study is to elucidate the effect of the anatomical asymmetry of long bones upon their torsional strength and

The study was supported by the Swedish Research Accident Insurance

Table 2 *Stiffness of paired long bones (femora and tibiae from 20 dogs)*

	Dog no	Stiffness Nm/degree		Percentage difference
		Inward rotation	Outward rotation	
femora	1	1.42	1.54	-8.1
	2	1.40	1.33	5.1
	3	1.30	1.40	-7.4
	4	1.33	1.38	-3.7
	5	1.75	1.67	4.7
	6	1.67	1.69	-1.2
	7	1.53	1.53	0.0
	8	0.71	0.69	2.9
	9	1.00	1.08	-7.7
	10	0.77	0.75	2.6
tibiae	11	0.79	0.85	-7.3
	12	1.00	0.96	4.1
	13	0.89	1.00	-11.6
	14	0.75	0.75	0.0
	15	0.58	0.56	3.5
	16	0.94	0.89	5.5
	17	1.19	1.25	-4.9
	18	0.69	0.70	-1.4
	19	1.06	1.56	0.0
	20	1.11	1.11	0.0

Each of the paired bones was rotated inwardly and the contralateral one was rotated outwardly. The difference between the inwardly rotated and the outwardly rotated bone is expressed in per cent of the average value of the two bones. Angular velocity was 6 degrees/second. The rotational direction had no significant influence on the stiffness. (Mean = -1.25 per cent, SD = 5.1 per cent. Paired *t* test 0.05)

Twist is the same for both bones with respect to the bone geometry, but if one bone is twisted inwardly and the other outwardly, the twist direction is different with respect to the bone geometry.

The evident difference in geometry between the two bones of a related pair might be taken to suggest that the torsional strength depends upon the direction of twist. The torsional strength depends, however, not only on the geometry of the long bone segments, but also upon the internal architecture and the distribution of the quantity of bone material. Varying quality and the presence and distribution of inhomogeneities in different parts of the diaphyseal bone segments. The

asymmetry of diaphyseal bones is most pronounced in the bone segments where the main muscle attachments are situated and in segments close to the bone ends. The asymmetry, however, decreases steadily as the bone segment where the area of muscle attachment attains a minimum is approached. In this segment the bones are almost cylindrical and the difference in geometry is consequently smallest. As minor variations in geometry of an idealized homogeneous body, according to the theory of strength of materials (Burrstein & Frankel 1971), have little effect on the torsional strength, the effect of the remaining difference in geometry is of minor importance.

The cylinder construction is a reasonable compromise to minimize the weight of a body to sustain axial, bend and torque loads acting individually or in combination

As regards torque, the geometrical asymmetry is obviously compensated for by a corresponding asymmetry of the internal bone architecture so as to render the torsional strength independent of rotation direction. This is evidently a logical consequence of the principle of adaptation to functional demands.

Stiffness is a well defined and easily quantified mechanical property of a body. It defines the twist response of the bone to a given torque. The stiffness of an anatomically asymmetric canine bone is independent of the direction of twist, or, the twist deformation of the bone is of the same magnitude for inward or outward twist with a given torque. This is also an evident consequence of the principle of adaptation to functional demands.

Furthermore, the present results show that the maximum torque capacity and the stiffness of canine long bones are both symmetrical properties, or, independent of the direction of twist. This indicates the ability of a long bone to adapt itself to the load bearing functional demands, in spite of a less favourable outer geometry, caused by the necessary soft tissue attachments. The use of one long bone of a related pair as a torsional test specimen, and the other as a control, with no regard to the direction of twist, is therefore justified.

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VALUATION OF FRACTURE HEALING IN MAN BY RAT ^{99m}Tc -Sn-PYROPHOSPHATE SCINTIMETRY

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Serial ^{99m}Tc -pyrophosphate ($^{99m}\text{TcPP}$) uptake measurements were performed, during the healing period, in 12 patients with fracture of the distal end of the radius without displacement. A peak value in uptake ratio was seen within 4 weeks in all patients. For clinical reasons the patients were divided into a normal healing and a slow healing group. $^{99m}\text{TcPP}$ uptake at 6 weeks after the fracture was significantly higher in the slow healing group. Quantitation of the healing process in forearm fractures is possible using $^{99m}\text{TcPP}$ and a gamma camera and concentrating on small selected areas of interest.

Key words: forearm fracture, scintimetry, ^{99m}Tc -pyrophosphate healing course

Accepted 8 May 78

The use of ^{99m}Tc -Sn-pyrophosphate ($^{99m}\text{TcPP}$) as a radio-pharmaceutical in clinical work is well established in the early diagnosis of skeletal metastases and primary bone tumours. Furthermore, a great deal of interest has been devoted to the application of other radioactive tracers to study osteogenesis of the head of the femur in fractures, of the tibial shaft displaying delayed and non-union, infected endoprotheses and some metabolic bone diseases (Merrick

1964). The purpose of the present study was to evaluate the use of $^{99m}\text{TcPP}$ in the diagnosis of fracture of the distal end of the radius during the healing period, and to correlate the clinical healing to $^{99m}\text{TcPP}$ scintimetry.

MATERIAL AND METHODS

Twelve patients, all women aged from 40 to 76 years (mean 56 years) were examined. All had fractures, without displacement of the distal end of the radius. The patients were selected in such a way that the radiological appearance of the fractures was identical.

Scintigraphy was performed every second week over a period of 8 to 10 weeks after the trauma. A final scintigraphy was made 24 weeks after the accident in eight of the patients. In four patients the final scintigraphy was omitted in one case because of refracture, in one because of operation on the wrist and the remaining two patients refused further follow-up.

In 10 patients admitted for bone scintigraphy because of diseases in the spine or lower extremities but without any injury or disease in the

Bone-seeking tracers have been less intensively studied during normal healing processes, although this application has been suggested by several authors (Bauer & Bessler 1959, Wendeberg 1961, Bessler 1968, Bauer 1975, Puranen et al. 1975, Hall et al. 1976).

The present study was undertaken to investigate the change in $^{99m}\text{TcPP}$ uptake in a



Figure 1 Scintigraphic appearance of forearms and hands (A) digitalized picture in 64×64 point frame (B) 2×2 points area of interest at the fracture site and a symmetrical area on the contralateral arm

upper extremities, a single scintigraphy of the forearms was obtained as a control.

A total of 61 scintigraphic examinations were performed.

Six to 10 mCi $^{99m}\text{TcPP}$ (Solcoscant $^{\circ}$ Diphosphate, Solco Nuclear Basle, Switzerland) was given intravenously. Three hours later scintigrams were obtained with a General Electric Maxicamera using a high resolution parallel hole low energy collimator. The systemic resolution was 10 mm. 250 000 counts were collected and the data stored on magnetic tape in a 64×64 points frame for later digital analysis (General Electric Med Stor $^{\circ}$).

In order to obtain reproducible and symmetrical geometry a PVC mould with excavations for the forearms was used. The dorsal plaster casts were left *in situ* and the forearms were examined from the volar surface.

In the digitalized picture of the forearms an area of interest was selected in the fracture region being the area showing the maximum of collected counts. A symmetrical area of the same size was located in the image of the contralateral forearm (Figure 1). The size of the areas chosen (2×2 points in the frame) was the minimal area which was possible using the available equipment. The area corresponded to approximately 16×16 cm on the examined object. In the non injured control patients equivalent areas in the distal end of the radius were examined.

The uptake of $^{99m}\text{TcPP}$ in the fracture was expressed as the ratio between the counts recorded in the two areas described. 3 500–15 000 counts were recorded in the fracture site and

500–2 000 in the contralateral arm. Thus the coefficient of variation of the ratios between the fracture site and the control arm was less than 45 per cent.

Healing of the fracture was evaluated by recording disappearance of local pain and achievement of free mobility. The clinical examination was carried out by a member of the staff of the orthopaedic department who had no knowledge of the scintimetric results. Additionally the immobilization time in plaster was recorded.

Blood samples were collected to estimate the calcium and vitamin D status. 25 hydroxy cholecalciferol was measured by a competitive protein binding assay according to Haddad & Chyu (1971).

Statistical evaluation was made using Wilcoxon rank sum tests for paired and unpaired data.

RESULTS

As illustrated in Figure 2 a variation in the $^{99m}\text{TcPP}$ uptake rate was seen after the fracture.

The accumulation of $^{99m}\text{TcPP}$ increased to reach a maximum within 4 weeks after the injury. This was followed by a decrease to the lowest values 24 weeks after the fracture.

A fracture of the distal end of the radius without displacement is normally united and free of local pain within 5 weeks. Based upon

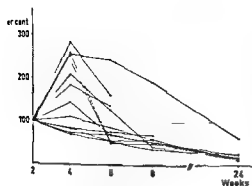


Figure 2 The percentage variation of $^{99m}\text{TcPP}$ uptake ratio related to the 2-week value

his criterion the patients were separated into two groups (Table 1). Seven patients healed within 5 weeks and five patients had a healing time of more than 5 weeks. Furthermore, the latter group required a significantly longer period for full mobility of the wrist and fingers to be achieved ($P < 0.05$). The plaster casts were applied for shorter period in the fast healing group, but the difference was not significant.

The results of scintimetry showed no difference between the two groups after 2 and

4 weeks, whereas the $^{99m}\text{TcPP}$ uptake 6 weeks after the fracture was significantly higher in the slow-healing group ($P < 0.05$). No difference was seen after 8 and 24 weeks (Table 2).

After 6 weeks all patients with normal healing had values below those found in the second week. This was, however, also found in one patient in the slow-healing group.

Normal values of serum calcium (2.12 ± 0.26) and (2.15 ± 0.20) and slightly elevated 25-hydroxycholecalciferol values (50.5 ± 14.8) and (40.3 ± 15.4) were seen in the normal and the slow-healing groups, respectively.

The patients without fractures had uptake ratios of 0.93 ± 0.05 (mean \pm s.d.).

DISCUSSION

The present investigation was undertaken to study the scintigraphic course of healing of fractures of the distal end of the radius. This type of fracture was chosen because the healing usually proceeds without delayed or

Table 1 Clinical evaluation of healing in normal (A) and slow healing (B) patients

Group	Disappearance of local pain (range in weeks)	Fixation with plaster casts (range in weeks)	Free mobility (range in weeks)
A	4-5	4-5	6-7
B	6-10	5-7	8-11
		NS	$P < 0.05$

Table 2 Variation of uptake ratio in the normal (A) and slow healing group (B) (Mean \pm s.d.)

Weeks	2	4	6	8	24
Group A $n=7$	10.3 ± 3.9	12.2 ± 3.2	6.7 ± 3.7	4.8 ± 3.0	1.8 ± 0.7
Group B $n=5$	8.6 ± 3.0	15.7 ± 3.9	11.5 ± 2.4	7.6 ± 3.1	2.5 ± 1.3
	NS	NS	$P < 0.05$	NS	NS

non union The availability of reproducible values from the contralateral arm also makes these fractures particularly suitable for this kind of study Moreover, it might serve as a model for the healing process of other types of fractures where exact clinical and radiological evaluation is more difficult

In the first radionuclide uptake study in fractures in man, Bauer & Wendeborg (1959) demonstrated with cation tracers ^{85}Sr and ^{45}Ca a maximal activity 6 weeks after a hip fracture These patients were investigated under rather varying conditions

Scintimetric evaluation of fracture healing has been carried out on tibial shaft fractures (Wendeborg 1961, Muheim 1973, Puranen et al 1975) Generally the maximum uptake at the fracture site was seen 4–8 months after the injury In delayed healing Bauer & Wendeborg (1959) found a high uptake ratio, whereas Puranen et al (1975) observed low uptake ratios in delayed union This discrepancy was noted by Muheim (1973) and may be related to different types of delayed union

In the present study a different tracer was used $^{99\text{m}}\text{TcPP}$ is preferentially bound by immature collagen, whereas the cation tracer ^{45}Ca is bound predominantly in the bone mineral (Kaye et al 1975) This may explain the earlier peak activity seen in our studies Furthermore, it is well known that there are differences in the natural healing course of fractures of the forearm and tibial fractures

The combination of good information density and safety of the radionuclide deposit at the lesion site, facilitated by the vascularity of the fracture make $^{99\text{m}}\text{TcPP}$ a good tracer for describing the events of fracture in the healing period (Lentle et al 1976)

As mentioned earlier maximal activity in small selected areas of interest was measured because they were exactly defined and reproducible when working with a digitalized computer system connected to a gamma camera This is in accordance with the results reported by Gumerman et al (1977) who were able to indicate the course of healing by sequential scanning with quantitative analysis

of the fracture line in a rabbit model using $^{99\text{m}}\text{Tc}$ methylenedisphosphonate

A relation between osteoporosis, osteomalacia, and occurrence of juxta articular fractures has been described (Aaron et al 1974) Seventy per cent of women with such fractures are osteoporotic (Bollet et al 1965). Furthermore, it has been demonstrated that 30 per cent of osteoporotic patients have histological but not biochemical signs of osteomalacia (Lund et al 1977 Sørensen et al 1977) Thus we examined Se-calcium and 25 OH-cholecalciferol to evaluate the vitamin D metabolism This metabolite affords the best evaluation of vitamin D-status according to Avioli & Haddad (1977) The metabolic analyses were done to exclude differences in vitamin D metabolism in the groups described Several authors (Harris et al 1965, Rosenthal & Kaye 1975, Fogelman et al 1977) have described alteration in radionuclide uptake in patients showing hypo- as well as hypervitaminosis D

Our preliminary investigation indicates that it is possible to quantitate the healing process using $^{99\text{m}}\text{TcPP}$ and a gamma camera and concentrating on small areas of interest By this method fractures of the distal end of the radius can be separated into normal and slow healing types This technique can probably be applied to other fractures

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STRUCTURAL ROLE OF BONE APATITE IN HUMAN FEMORAL COMPACTA

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Tensile and compressive strength of human femoral compacta have been shown to be related ($P < 0.005$) to the average bone apatite crystallite length (D_{002}) as determined by X-ray diffraction line breadth measurement. However, statistical variance of crystallite length was not sufficient to explain observed differences in mechanical properties these differences being primarily due to variation in mineral density. Average bone apatite

but that this is not a major factor in determining fracture incidence in the elderly

Key words: bone apatite, crystallite length, mechanical properties

Accepted 14 iv 78

Compact bone is a composite material comprising collagen fibrils set in a non-collagenous matrix and incorporating calcium hydroxyapatite-like mineral inclusions (Wainwright et al. 1976). In addition, Posner (1969) has reported the presence of mineral in the form of amorphous calcium phosphate in bone. Correlation of the mechanical properties of bone tissue with mineral content is well established (Vose & Kubala 1959, Vose et al. 1961, Mather 1968, Currey 1969, Currey & Butler 1975), and increased incidence of bone fracture in the elderly (Knowelden et al. 1964) has been related to a decline in bone mineral content with age (Mulligan et al.

1975). Despite evidence of age-related change in bone apatite crystallite length and orientation (Chatterji & Jeffery 1968, Chatterji et al. 1972), the structural role of apatite in compact bone has not been directly investigated.

We have used X-ray diffraction line breadth measurement (Holmstrand 1957) to assess average bone apatite crystallite length (D_{002}) in human bone samples of differing biological age. Tensile and compressive mechanical properties were measured in the same bones and considered in relation to crystallite length.

MATERIALS AND METHODS

Human compacta excised post-mortem from 14 males and 15 females, ranging from 3½ to 87 years of age, was studied. All samples were removed from the proximal half of the femoral shaft, placed in polythene bags to prevent drying, and stored at -20°C until required. Separate portions were designated for the preparation of tensile and compressive test-pieces and X-ray diffraction powder samples. A steel template was used to prepare tensile test pieces 3.1 mm thick and with a "waisted" portion 35 mm in length and 3.8 mm in width. Cylindrical compressive test-pieces 5.1 mm in diameter and 7.5 mm in length were produced with a diamond tipped core drill. Where the bone was of sufficient size, mechanical test-pieces were produced from four cross-sectional quadrants, thus moved possible with 27 bones in the case of compressive test-pieces, and with 24 bones in the case of tensile test-pieces. Mechanical test-pieces remained moist when tested to destruction at a strain rate of 10^{-3} s^{-1} , as described in an earlier publication (Smith & Smith 1976a). The values of both tensile or compressive property determined on the four quadrants in each bone were averaged to reduce variation due to regional differences.

X-ray diffraction bone powder samples were reduced by crude milling and subsequent wet-milling with isopropyl alcohol in a micronizing mill. Grinding for 2 minutes produced a powder with particle size in the range 50–150 micron. The minimum particle dimension was large enough to ensure that the surface layer, which might contain crystallites ground to a size sufficiently small to produce X-ray diffraction line broadening, comprised less than one per cent of particle volume (Smith 1975). The line profile of the bone apatite (002) reflection obtained using nickel-filtered copper K_{α} radiation was monitored with a Philips vertical goniometer Type PW 1140. The goniometer was fitted with 1° divergence and scatter slits and a 1 mm receiving slit, and the diffraction detector was rotated at 1°/20 per minute. Instrumental line broadening produced by this experimental arrangement was measured by recording the (111) reflection for each of ten NaCl standard powder samples possessing crystallite size too large (50–150 micron) to contribute to line broadening.

Calculations

Bone apatite (002) X-ray diffraction line profiles were shown to be described accurately ($r \geq 0.99$) by the Cauchy equation $y \approx 1/(1 + K^2 X^2)$. Observed line breadth at half peak intensity was corrected for broadening due to wavelength spread

accurate estimate of instrumental line broadening at a diffraction angle close to that of the bone apatite (002) reflection. Hence, bone apatite (002) pure line breadth (β_{002}) was calculated by the method of Alexander & Klug (1950).

Pure line breadth results from small crystallite size and lattice strain (Warren & Averbach 1950). Harper & Posner (1966) have claimed that bone contains amorphous calcium phosphate (ACP), which causes diffuse X-ray scattering and gives rise to additional line broadening. However, ACP converts rapidly to hydroxyapatite in the presence of the precipitating solution (Termine et al 1970), and there is no satisfactory theory to explain why this should not occur *in vivo*. The authors (Smith & Smith 1976b) do not believe that bone contains a substantial quantity of ACP, and Posner et al (1975) now even express some uncertainty as to the short-term presence of ACP in bone as a chemical precursor in the formation of bone apatite *in vivo*.

Moreover, calculation based on accepted values for the rate of bone turnover in the adult (Villanueva et al 1966) shows that if ACP is precipitated in bone and converts to hydroxyapatite within 24 hours, then the proportion of amorphous bone mineral will be less than 0.01 per cent of the total, and would not significantly affect X-ray diffraction line breadth.

It is known that the Cauchy form of pure line profile, as observed in our investigation, is characteristic of pure line broadening due to small crystallite size (Posner et al 1965, Schoening 1965). Thus, an estimate of bone apatite average crystallite size (D_{002}) normal to the (002) planes, can be calculated from the Scherrer equation

$$D_{hkl} = C \lambda / \beta_{hkl} \cos \theta_{hkl}$$

where λ is the intensity-weighted mean wavelength of X-radiation, θ_{hkl} is the Bragg angle for the (hkl) planes, β_{hkl} is the pure line breadth measured in radians, and C is a constant dependent upon the definition of β and the crystallites shape distribution. Absolute determination of D_{hkl} is inaccurate due to uncertainty as to the value of C , although Bragg (1919) has shown that if β is defined as the pure line breadth at half maximum intensity, then C takes a value of approximately 0.9 and is relatively insensitive to differences in shape. This value of C was assumed in the present investigation. Since the bone apatite c-axis has been shown to be parallel to the long axis of the crystallite (Engstrom & Funes 1953), D_{002} is equal to the average crystallite length.

STRUCTURAL ROLE OF BONE APATITE IN HUMAN FEMORAL COMPACTA

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Tensile and compressive strength of human femoral compacta have been shown to be related ($P < 0.005$) to the average bone apatite crystallite length (D_{002}) as determined by X-ray diffraction line breadth measurement. However, statistical variance of crystallite length was not sufficient to explain observed differences in mechanical properties, these differences being primarily due to variation in mineral density. Average bone apatite crystallite length was not found to change significantly with biological age ($P = 0.30$) over the range 3½ to 87 years. It is concluded that increased bone apatite crystallite length is detrimental to the structural role of the skeleton but that this is not a major factor in determining fracture incidence in the elderly.

Keywords: bone apatite, crystallite length, mechanical properties

Accepted 14 iv 78

Compact bone is a composite material comprising collagen fibrils set in a non-collagenous matrix and incorporating calcium hydroxyapatite-like mineral inclusions (Wainwright et al 1976). In addition, Posner (1969) has reported the presence of mineral in the form of amorphous calcium phosphate in bone. Correlation of the mechanical properties of bone tissue with mineral content is well established (Vose & Kubala 1959, Vose et al 1961, Mather 1968, Currey 1969, Currey & Butler 1975), and increased incidence of bone fracture in the elderly (Knowelden et al 1964) has been related to a decline in bone mineral content with age (Mulligan et al

1975). Despite evidence of age-related change in bone apatite crystallite length and orientation (Chatterji & Jeffery 1968, Chatterji et al 1972), the structural role of apatite in compact bone has not been directly investigated.

We have used X-ray diffraction line breadth measurement (Holmstrand 1957) to assess average bone apatite crystallite length (D_{002}) in human bone samples of differing biological age. Tensile and compressive mechanical properties were measured in the same bones and considered in relation to crystallite length.

DYSTROPHIC CALCIFICATION IN TUBERCULAR LESIONS OF BURSAE

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Four patients with extensive dystrophic calcification in osteoarticular tubercular lesions of relatively short duration, are described. All lesions healed satisfactorily after treatment with antitubercular drugs combined in some cases with *en bloc* excision.

Key words: dystrophic calcification, lymph nodes, tubercular lesions, osteoarticular tuberculosis

Accepted 9 III 78

Dystrophic calcification in long-standing lesions of lymph nodes and is a known entity. However, extensive dystrophic calcification in osteoarticular tubercular lesions of shorter duration has not been reported. Hence, the clinical, radiological, operative and histopathological features of four such patients with extensive dystrophic calcification around the hip and knee are described.

CASE REPORTS

Case 1
A 30-year-old man, presented in November 1973 with a 6-year history of pain and swelling over the left trochanteric region and the knee of similar swelling and pain over the right trochanteric region in the course of the last 3 years. The swellings were associated with fever. Following treatment with antibiotics and antitubercular drugs the swellings had temporarily but gradually the symptoms recurred.

Physical examination of the patient at the initial admission revealed a diffuse swelling on either side of the trochanteric and gluteal region. There

was a sinus on the left side, discharging thin serous fluid. The skin around the sinus was pigmented and adherent to the underlying

were enlarged and tender. There were no clinical signs of hip joint disease.

Radiological examination showed extensive calcifications of the trochanteric region of both hips without any involvement of the joints or the pelvic bones (Figure 1).

Exploration of the right swelling produced necrotic and calcareous matter. Histological examination of the specimen showed a characteristic tubercular lesion with dystrophic calcification (Figure 2).

Following treatment with antitubercular drugs the lesions healed.

Case 2

M.A., a 12-year-old boy was admitted on 12.10.76 with complaints of a tender swelling in the left gluteal region. The symptoms had begun after a fall from a bicycle 11 months previously. The swelling had increased in size with episodes of fever and decreased after treatment, in 7-10 days. At admission of diffuse swelling (Figure 3) was seen and on deep palpation a hard mass with restricted mobility was felt under the gluteus maximus. Local temperature was raised. The boy



Figure 1 X ray of the pelvis including both hips shows an extensive calcified mass in the trochanteric region on both sides (Case 1)

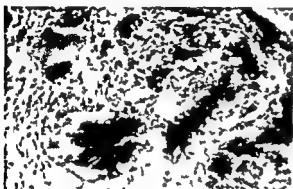


Figure 2 Microphotograph of Case 1 showing tubercular granulomas with large areas of calcification. Note also one large giant cell with bipolar arrangement of the nuclei (H&E $\times 160$)



Figure 3 Clinical photograph showing diffuse swelling in the left trochanteric region (Case 2)

had lumbar lordosis and with the exception of a flexion deformity of 40 degrees, the hip joint was clinically free from disease. Wasting of the glutei and the quadriceps muscles was also present. A ray of the region showed a soft tissue swelling and extensive calcification similar to Case 1.

The swelling which was situated beneath the gluteus maximus, was excised and was found to consist of tubercular pus with cheesy material and calcified masses.

Microscopic examination showed a tubercular lesion with extensive dystrophic calcification. The patient recovered satisfactorily following treatment with antitubercular drugs.

Case 3

DN., a 17 year-old boy attended the hospital in July 1974 with complaints of a swelling of the anteromedial aspect of the left elbow of insidious onset 1 year previously (Figure 4). The elbow was ankylosed in extension because of an accident 3 years earlier.



Figure 4 Clinical photograph showing swelling over the front of the elbow (Case 3)

Clinical examination revealed a localized, tense, fluctuant nonpulsatile swelling over the anteromedial aspect of the left elbow. Movement of the elbow was restricted to 0–30 degrees.

Radiological examination of the elbow showed a well-delimited, pedunculated soft tissue swelling arising from the anterior aspect of the elbow joint with evidence of extensive calcification within the swelling. There were destructive changes in the elbow joint (Figure 5). En bloc excision of the swelling was performed. It contained tubercular pus and calcified debris.

The patient made a good recovery after treatment with antitubercular drugs and even regained a good range of elbow motion.



Figure 5 X-ray of the left elbow showing well delineated, pedunculated cystic swelling over the anteromedial aspect of the elbow joint (Case 3)



Figure 6 X-ray of the right elbow showing soft tissue swelling with a calcified mass behind the distal end of the humerus and the elbow joint (Case 4)

Case 4

M.D., a 7-year-old girl, presented with complaints of pain and swelling on the posterior aspect of the right elbow which had begun 2 months previously. Clinical examination revealed a well defined oblong non tender swelling along the posterior aspect of the lower fourth of the arm. The swelling was mobile with a variable consistency from soft and fluctuant to hard and nodular. The local temperature of the swelling was raised. Elbow motion ranged from 30–120 degrees. Axillary lymph nodes were enlarged and tender.

The patient also had a discharging sinus from her right tibia.

X-rays of the elbow and tibia showed periosteal reaction and sclerosis in the upper third of the tibia.

En bloc excision of the swelling was performed. The mass contained typical tubercular pus with cheesy material and a calcified nodular mass. The patient regained full function of the elbow following antitubercular drugs.

DISCUSSION

Deposition of calcium salts in dead and non-vital tissues is termed dystrophic calcification and is found in various pathological conditions. Tuberculosis is one of the commonest causes (Anderson 1971, Florey 1970). Dystrophic calcifications are found most

frequently in lymph nodes and in cold abscesses of long standing. In the four cases presented here, extensive dystrophic calcification was seen in three cases of relatively short duration, i.e., 2 months to 1 year, the first case had a disease process lasting 6 years. All the four cases posed clinical and radiological diagnostic problems and the tuberculous nature of the lesions was revealed only after exploration and histopathological examination. Even though tuberculosis in general and osteoarticular tuberculosis in particular is very common in our country, such extensive dystrophic calcification is very unusual and to our knowledge has not been described earlier in the literature.

ACKNOWLEDGEMENT

Sincere appreciation is expressed to Mr D K Mathur for photographic assistance and to Sri Prem Nath for secretarial assistance.

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ATROPHY OF CORTICAL BONE CAUSED BY RIGID INTERNAL FIXATION PLATES

An Experimental Study in the Dog

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The cortical atrophy induced by a rigid internal fixation plate on diaphyseal bone was studied on the femora of seven dogs. When the plate which had been in position for 7 months without previous osteotomy, was removed a pronounced reduction of the cortical bone was observed in the previously plated section of the diaphyseal bone. The atrophy took the form of loss of cortical bone mainly caused by endosteal resorption with enlargement of the medullary cavity. Neither periosteal resorption nor formation of woven bone under the site of the plate were observed. The process of adaption to the changed stress and strain conditions, caused by the mechanical joint, i.e., implants and bone was studied by means of a histological technique, and was still in progress after a period of seven months.

Key words: internal plate fixation, adaption of cortical bone to functional demands, measurement of cortical bone atrophy

Accepted 22 x.77

Metal plates for internal fixation have been used to an ever increasing extent for almost a century. Clinical experience from fracture treatment with internal fixation plates shows, however, that a considerable number of refractures occur (Richon et al 1967, Wade 1970). In a previous paper (Strömberg & Dalén 1976), we demonstrated that the dog femur stabilized with a rigid internal fixation plate (AOI-type) for 7 months displays, on removal of the plate, and compared with the contralateral control bone, a significantly different distribution of bone and a marked reduction in mechanical strength of torsion.

METHODS

Anaesthesia

The surgical procedures for bone plating according to the AO group were performed under general anaesthesia which was induced with thionembutalnatrum (Pentothal Sodium[®], Abbott Laboratories Chicago, Ill. USA). By means of an endotracheal tube, the dogs were connected to an Engstrom ventilator supplied with a gas mixture of oxygen and nitrous oxide. Small doses of thionembutalnatrum were administered intermittently during the operations.

Surgical

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The present study elucidate the mechanism of development of bones caused by the

healthy male dogs (Swedish) were used. An AO four holes designed for use on dogs (Synthes) was applied under sterile conditions. An incision was

made through the skin and underlying fascia. Both femora were exposed up to the linea aspera by an approach behind and under the vastus lateralis muscle of the quadriceps along the intramuscular septum (the 'mailbox' approach). The underlying periosteum was not detached from the bone and no osteotomy was performed. The perforating vessels in the distal part of the intramuscular septum were used as reference points, so that the plates could be similarly fitted on both femora. The plates were applied to both femora immediately in front of the linea aspera and fastened according to the AO method, after the plate had been modelled to the bone (Müller et al 1970). One of the plates (chosen at random) was removed and the screws refastened into the bone. The soft parts were sutured in stages, using catgut in the fascia and non-absorbable sutures in the skin.

Pre and postoperative care

During the operations, 500 ml of Ringer solution was administered intravenously. A daily prophylactic dose of 0.5 g of ampicillin (Pen streyl[®], Bristol-Myers, New York, N.Y., USA) was given during the first postoperative week. The dogs spent an uneventful postoperative period of 7 months in kennels. They were checked daily and received adequate food and exercise.

Seven months after the operations, the animals were given tetracycline (Terramycin[®], Pfizer Inc., New York, N.Y., USA), 0.5 g per kg body weight per os.

Sacrifice

One week after administration of tetracycline, the dogs were sacrificed with intravenous lethal doses of mebumalnatium (Nembutal[®], Abbott Laboratories).

Bone preparation

All femora were dissected from the surrounding soft tissue, but not from the periosteum. The femora, the test bones and the control bones, were cut in 4.0 mm thick cross-sectional slices. They were frozen to -40°C. All the slices were submitted to X-ray examination. After the radiological examination, every second slice was chosen for ashing and the rest for histological studies.

Radiological study

The radiological examinations were performed with the X-ray beams parallel to the long axis of the femora. The porosity of the cortical bone and

the amount of newly formed periosteal bone were estimated by means of the radiograms from the cross section of the bones. The cross-sectional areas of the cortical bone and those of the medullary cavities were measured with a planimetric technique. The areas were compared and the differences between those from the test bones and the corresponding ones from the control bones were noted. In the measurement of cross-sectional areas, the periosteal formed bone ridges were excluded.

Histological study

The slices chosen for histological studies by means of a fluorescence technique were freeze-dried to constant weight and then immediately embedded in methylnitroacrylate (Olerud & Lorenzi 1970). Thin pieces were cut from the embedded slices and then reduced to a thickness of about 60 μ . This process had no effect on the fluorochromes present. The colours were fixed by a freeze-drying process, as they would have been partly dissolved by other dehydration procedures. The prepared histological slides were studied by fluorescence microscopy. The differences between corresponding parts of the test bones and their controls were estimated.

Measurement of ash weights

The amount of non-organic material in the test bones and their controls was estimated by means of an ashing procedure. The slices chosen were ashed to constant weight at 600°C. The differences in ash weight between the ashes from corresponding slices from the same animal were registered.

RESULTS

Dispersed areas of periosteal formed bone were observed on the radiograms. The areas where the plates had been located were defined by ridges formed of periosteal bone, most pronounced at the ends of the sites of the plates. Where the tips of the screws had penetrated the periosteum, sub-periosteal bone had formed a cone around the tips. The radiograms of the cross sections under the midpoint of the internal fixation plates showed increased porosity compared with corresponding sections from the control bones. Areas of newly formed periosteal bone

9.0 M. LINES IN CM CUT SECTIONS

CROSS SECTION AREAS

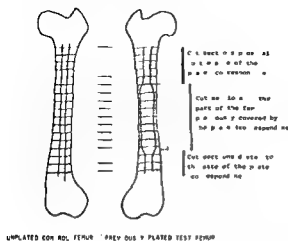


Figure 1 Cut sections of femur in which a rigid internal fixation plate (AOI-type) has been applied for 7 months and of the corresponding control femur not affected by a plate

Table 1 The mean values of the total areas of the bones and the deviation of the areas of the previously plated femora expressed as a percentage of the corresponding values of the respective control femora

and from the seven control femora. The areas are given in relative numbers. The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the respective control femora

Dog no	Control bone	Test bone	Percentage deviation
	Femur not affected by a rigid plate	Femur affected by a rigid plate	
1	352	353	-0.3
2	327	321	1.8
3	324	319	1.5
4	272	272	0.0
5	319	322	-0.9
6	300	297	1.0
7	303	298	1.6

The areas of the cross sections had not decreased under the site of the plate (mean = 0.67 per cent, SD = 1.06). Paired observation tests $t = 1.63$, $P > 0.05$

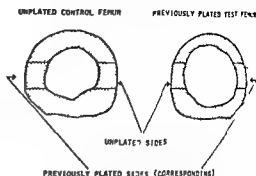


Figure 2 Standard partial cortical areas of cortical cross section from femur in which an internal fixation plate (AOI type) has been applied for 7 months and the analogous areas of the corresponding control femur

were observed on both the test and control bones

Planimetry of the total cross sectional areas of the bones, including the marrow cavity under the sites of the plates, displayed no significant reduction compared with the corresponding areas from the previously non-plated control bones (Table 1, Figure 1, Figure 2)

The cortical areas of the cross sections of those parts of the bones which had been covered by the plates showed a significant reduction as compared with the contralateral control cross sections (Table 2a, Figure 1, Figure 2)

The cortical cross-sectional areas on the plated side of the stabilized femora, excluding the periosteal formed bone, were not reduced in comparison with the opposite side of the same bone (Tables 3a, 3b, Figure 2)

There was however a pronounced enlargement of the medullary cavities of that part of the test bones previously covered by the plate compared with those of the control bones (Table 4, Figure 1, Figure 2)

The cortical cross-sectional areas proximal and distal to the sites of the plates showed no

Table 2 The mean values of parts of the cross-sectional areas representing the cortical bone (Figure 2) from ten cross sections under the site of

femora The areas are given in relative numbers. The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the respective control femora

(a) Cross sectional parts (cortical bone) proximal to the site of the plate (Figures 1, 2) (corresponding)

Dog no.	Control bone	Test bone	Percentage deviation
	Femur not affected by a rigid plate	Femur affected by a rigid plate	
1	200	185	-7.5
2	186	180	-3.2
3	181	199	9.9
4	157	187	6.4
5	196	196	0.0
6	154	150	-2.8
7	175	172	-1.7

The areas had not changed proximal to the site of the plate (mean = 0.2 per cent, SD = 5.98). Paired observation tests $t = 0.00$, $P > 0.05$

(b) Cross sectional parts (cortical bone) under the site of the plate (Figures 1, 2) (corresponding).

Dog no.	Control bone	Test bone	Percentage deviation
	Femur not affected by a rigid plate	Femur affected by a rigid plate	
1	222	194	-12.6
2	205	176	-14.1
3	197	167	-15.2
4	187	170	-9.2
5	191	174	-18.9
6	201	177	-11.9
7	185	173	-6.5

The areas had decreased under the site of the plate (mean = 11.2 per cent, SD = 3.13). Paired observation tests $t = 8.37$, $P < 0.05$

(c) Cross sectional parts (cortical bone) distal to the site of the plate (Figure 2) (corresponding)

Dog no.	Control bone	Test bone	Percentage deviation
	Femur not affected by a rigid plate	Femur affected by a rigid plate	
1	172	182	5.8
2	180	169	-6.1
3	184	197	7.1
4	184	173	-5.5
5	187	173	-3.2
6	183	182	-0.5
7	166	181	9.0

The areas had not changed distal to the site of the plate (mean = 2.5 per cent, SD = 5.76). Paired observation tests $t = 0.67$, $P > 0.05$

differences between the test and the control bones (Tables 2a, 2c, Figure 1, Figure 2)

Histological studies of the cortical bone previously covered by the plate showed a uniform distribution of increased osteoblast activity compared with the corresponding contralateral control femora

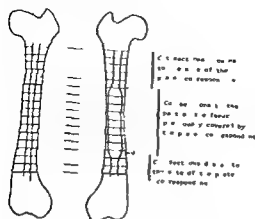
Furthermore, porosity was most pronounced in the endosteal part of the cortical bone of the test femora. Proximal to the site of the plates, there was no difference in porosity between the test and the control bones

Histologically, there was evidence of activity of periosteal bone formation in the previously mentioned ridges close to the internal fixation plates. This activity had, however, ceased in the areas of periosteal bone without connection with the internal fixation plates

The ashing procedure disclosed clearly reduced ash weights of the cross-sectional slices under the plates as compared with those of the control femora (Table 5b). There was no marked difference in the ash weights proximal to the site of the plate and the corresponding part of the control bone (Table 5a)

A 0 P L 1 MEASURES Y CK CUT SECT ONE

CROSS SECTION AREAS



UNPLATED CONTROL FEMUR PREVIOUSLY PLATED TEST FEMUR

Figure 1 Cut sections of femur in which a rigid internal fixation plate (AOI type) has been applied for 7 months and of the corresponding control femur not affected by a plate

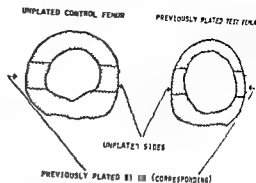


Figure 2 Standard partial cortical areas of cortical cross section from femur in which an internal fixation plate (AOI type) has been applied for 7 months and the analogous areas of the corresponding control femur

Table 1 The mean values of the total areas (cortical bone + bone marrow) (Figure 2) from ten cross sections under the site of the plate (Figure 1) in seven femora to which an internal fixation plate (AOI-type) had been applied for 7 months and from the seven control femora. The areas are given in relative numbers. The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the respective control femora

Dog no	Control bone Femur not affected by a rigid plate	Test bone Femur affected by a rigid plate	Percentage deviation
1	352	353	-0.3
2	327	321	1.8
3	324	319	1.5
4	272	272	0.0
5	319	322	-0.9
6	300	297	1.0
7	303	298	1.6

The areas of the cross sections had not decreased under the site of the plate (mean = 0.67 per cent, $SD = 1.06$). Paired observation tests $t = 1.63$, $P > 0.05$

were observed on both the test and control bones

Planimetry of the total cross sectional area of the bones, including the marrow cavity under the sites of the plates, displayed a significant reduction compared with the corresponding areas from the previously not plated control bones (Table 1, Figure 2)

The cortical areas of the cross sections of those parts of the bones which had been covered by the plates showed a significant reduction as compared with the contralateral control cross sections (Table 2a, Figure 1, Figure 2)

The cortical cross-sectional areas on the plated side of the stabilized femora, excluding the periosteal formed bone, were not reduced in comparison with the opposite side of the same bone (Tables 3a, 3b, Figure 2)

There was however a pronounced enlargement of the medullary cavities of that part of the test bones previously covered by the plate compared with those of the control bones (Table 4, Figure 1, Figure 2)

The cortical cross-sectional areas proximal and distal to the sites of the plates showed no

Table 4 The mean values of the bone marrow areas (Figure 2) from the cross sections under the site of the plate (Figure 1) in seven femora to which an internal fixation plate (AOI-type) had been applied for 7 months and from the seven control femora. The areas are given in relative numbers. The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the control femora

Dog no	Control bone	Test bone	
	Femur not affected by a rigid plate	Femur affected by a rigid plate	Percentage deviation
1	130	159	22.3
2	122	145	18.9
3	127	152	19.7
4	85	102	20.0
5	128	148	15.6
6	99	117	18.2
7	118	125	5.9

The areas had increased under the site of the plate (mean = 17.2 per cent, SD = 5.39). Paired observation tests $t = 7.47$, $P < 0.05$

Table 5a The mean values of the ash weights from the cut sections proximal to the site of the plate (Figure 1) in seven femora to which an internal fixation plate (AOI type) had been applied for 7 months and from the seven control femora. The weights are given in mg. The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the control femora

Dog no	Control bone	Test bone	
	Femur not affected by a rigid plate	Femur affected by a rigid plate	Percentage deviation
1	0.5057	0.5038	0.4
2	0.4510	0.4493	-0.4
3	0.5064	0.4971	-1.8
4	0.4079	0.4261	4.5
5	0.4468	0.4558	2.0
6	0.3746	0.3833	2.3
7	0.4181	0.3989	-4.5

The ash weights had not changed proximal to the site of the plate (mean = 0.3 per cent, SD = 2.98). Paired observation tests $t = 0.11$, $P > 0.05$

visualized by the markedly decreased total cross-sectional cortical area.

The diameter of the medullary cavity increased. It was not, however, associated with a change in the outer diameter of the test bone. This was taken as evidence that the reduction of material occurs in the endosteal parts of the stabilized bone sections in accordance with the results of Akeson et al but in disagreement with the suggestion of Tonino et al (1976).

The weakening of the cortical cylinder, measured as a reduced resistance to bending and torque loads, acting in combination or individually, is thus minimized due to the fact that the reduction takes place in the endosteal parts of the cortical wall.

The decrease in bone material asserted itself not only as reduced cortical cross section area, but also in increased porosity. The ash weight determinations were in accordance with the decreased bone material content in the stabilized sections. This does

Table 5b The mean values of the ash weights from the cut sections under the site of the plate (Figure 1) in seven femora to which an internal fixation plate (AOI type) had been applied for 7 months and from the seven control femora. The weights are given in mg. The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the control femora.

Dog no	Control bone	Test bone	
	Femur not affected by a rigid plate	Femur affected by a rigid plate	Percentage deviation
1	0.5876	0.4848	-16.8
2	0.4172	0.3459	-17.1
3	0.4903	0.4025	-17.9
4	0.4308	0.3808	-11.6
5	0.4134	0.3616	-12.5
6	0.4277	0.3486	-18.5
7	0.5026	0.4166	-17.1

The ash weight had decreased in the part of the bone previously covered by the plate (mean = 15.9 per cent, SD = 2.72). Paired observation tests $t = 10.29$, $P < 0.05$

not seem to be in full agreement with the observation of Woo et al (1976) that the mechanical changes due to internal fixation plating were a result of reduction in the cortical bone structure by thinning of the cortex rather than a reduction in the mechanical properties of the bone substance.

In the present study no increased cross-sectional area or elevated ash weight proximal or distal to the sites of the plates were observed as signs of increased quantity of bone material. This was to be expected as according to mechanical principles there should be increased stress and strain concentrations and, thus, an increased bone formation.

In the present experiments, however, the plates were long when compared with plated diaphyseal bones. The non-covered parts of the bones formed rather short mechanical joints, which together with the geometry of these parts probably explains why the bone substance had markedly increased proximal to the site of the plate.

The operative procedure with the application of the rigid metallic plate by means of screws will cause compression of the periosteum and the underlying bone. There will be damage to the periosteum and this affects the blood flow situation in the cortical bone and may be partly responsible for the formation of woven bone as observed by Matter et al (1974). This woven bone was placed as a reflection of the plate in the cortex immediately covered by the plate. The dynamic process of altering the blood flow in the cortical bone has been discussed (de Marneffe 1957, Göthman 1960, Brookes 1971). However, the cortical bone is able to compensate for the loss of limited periosteal blood flow, and, 7 months after surgery, we could not find any local effects on the cortical bone due to disturbed blood supply.

These observations are in accordance with those of other investigators (Akeson et al 1976, Tonino et al 1976, Woo et al 1976), but as mentioned above do not harmonize in this respect with the results reported by Matter et al (1974) or the clinical

observations reported by Diel & Mittelmeier (1974). The differences in species and postsurgical observation times are probably the reasons for this discordance between our results and those of Matter et al (1974).

In contrast to earlier reports we could not demonstrate that the adaption was most pronounced in that portion of the cross section previously covered by a plate. Akeson et al (1976) and Woo et al (1976) in their joint material, and Matter et al (1974) observed a decreased thickness of the cortical bone under the site of the rigid plate due to an endosteal resorption. The entire section of the long bone and the fastened rigid metallic plate covering the bone section formed the mechanical joint. Thus there was a changed load situation in the whole bone part of the thus formed mechanical joint with decreased stress and strain in the part covered by the plate as well as in the opposite part.

Despite the fact that we have excluded the small periosteally formed bone ridges in our cross-sectional area measurements, it is difficult to explain the dissimilarity of the observed cortical atrophy under the plate in our material and that of the previous reports.

The results of the present investigation are in agreement with our earlier findings (Strömberg & Dalén 1976). The decreased amount of bone material, the observed porosity and the reduction of the cortical wall of the bone with unchanged outer diameters are, according to the principles of strength of materials and solid mechanics, consistent with a decreased maximum torque capacity and maximum angle of torsion at torsional tests reported in previous papers.

The histological findings indicated, in this study, an increased osteoblast activity in the test bones compared with the control ones, which would suggest that the reconstruction, i.e. the adaption, was not completed after 7 months. Furthermore, neither the momentum of the adaption process nor of the following re-adaption process or its mechanism are yet known. A diaphyseal fracture in a dog femur is generally considered clinically healed within a shorter period than 7 months when treated

by means of rigid internal plate fixation. These facts, together with our previous and present results, indicate the importance of minimizing the period that the internal fixation plate should protect the bone during fracture treatment from loads, as the protection has an ongoing detrimental effect upon the strength qualities of the bone.

The use of internal fixation plates made from less rigid materials than stainless steel is reported in the literature (c.f. Woo et al 1974, Akeson et al 1976, Woo et al 1976). The aim seems to be to decrease the weakening effect on the stabilized non-fractured part of the bone. To attain the desired rigidity of an internal fixation plate, it would be more practical to design a suitable stainless steel plate than to experiment with other materials of less rigidity. The elastic modulus of the material from which the plate is made is of minor interest in this respect. It is the stiffness of the designed plate that defines the quality of the performed internal fixation. Equal stiffness can be achieved even if the plates are made from different materials. Experiments with plates made from weaker materials than stainless steel are thus only of academic interest concerning the influence of the weakening effect on a non-fractured diaphyseal bone.

To achieve primary fracture healing, the fracture surfaces must be kept compressed and fixed against each other. The fractured limb may be expected to bear loads early during the healing process, and this can be sustained only if a rigid mechanical joint is formed, e.g. by means of a rigid plate according to the AO-method. Otherwise the conditions for primary bone healing will not exist.

However, the problem remains of when to remove the implants and how to avoid unnecessary deterioration of the cortical bone, thus minimizing the time required for a fractured diaphyseal bone to regain its normal strength and architecture. Until this problem is solved, it cannot be considered that the principles of the treatment of fractures by

means of rigid internal fixation plates have been fully clarified.

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not seem to be in full agreement with the observation of Woo et al (1976) that the mechanical changes due to internal fixation plating were a result of reduction in the cortical bone structure by thinning of the cortex rather than a reduction in the mechanical properties of the bone substance.

In the present study no increased cross-sectional area or elevated ash weight proximal or distal to the sites of the plates were observed as signs of increased quantity of bone material. This was to be expected as according to mechanical principles there should be increased stress and strain concentrations and, thus, an increased bone formation.

In the present experiments, however, the plates were long when compared with plated diaphyseal bones. The non-covered parts of the bones formed rather short mechanical joints, which together with the geometry of these parts probably explains why the bone substance had markedly increased proximal to the site of the plate.

The operative procedure with the application of the rigid metallic plate by means of screws will cause compression of the periosteum and the underlying bone. There will be damage to the periosteum and this affects the blood flow situation in the cortical bone and may be partly responsible for the formation of woven bone as observed by Matter et al (1974). This woven bone was placed as a reflection of the plate in the cortex immediately covered by the plate. The dynamic process of altering the blood flow in the cortical bone has been discussed (de Marneffe 1957, Gothman 1960, Brookes 1971). However, the cortical bone is able to compensate for the loss of limited periosteal blood flow, and, 7 months after surgery, we could not find any local effects on the cortical bone due to disturbed blood supply.

These observations are in accordance with those of other investigators (Akeson et al 1976, Tonino et al 1976, Woo et al 1976), but as mentioned above do not harmonize in this respect with the results reported by Matter et al (1974) or the clinical

observations reported by Diel & Mittelman (1974). The differences in species and postsurgical observation times are probably the reasons for this discordance between our results and those of Matter et al (1974).

In contrast to earlier reports we could not demonstrate that the adaption was most pronounced in that portion of the cross section previously covered by a plate. Akeson et al (1976) and Woo et al (1976) in their joint material, and Matter et al (1974), observed a decreased thickness of the cortical bone under the site of the rigid plate due to an endosteal resorption. The entire section of the long bone and the fastened rigid metallic plate covering the bone section formed the mechanical joint. Thus there was a changed load situation in the whole bone part of the thus formed mechanical joint with decreased stress and strain in the part covered by the plate as well as in the opposite part.

Despite the fact that we have excluded the small periosteally formed bone ridges in our cross-sectional area measurements it is difficult to explain the dissimilarity of the observed cortical atrophy under the plate in our material and that of the previous reports.

The results of the present investigation are in agreement with our earlier findings (Stromberg & Dalén 1976). The decreased amount of bone material, the observed porosity and the reduction of the cortical wall of the bone with unchanged outer diameter are, according to the principles of strength of materials and solid mechanics consistent with a decreased maximum torque capacity and maximum angle of torsion at torsional tests reported in previous papers.

The histological findings indicated, in this study, an increased osteoblast activity in the test bones compared with the control ones, which would suggest that the reconstruction, i.e., the adaption, was not completed after 7 months. Furthermore, neither the momentum of the adaption process nor of the following re-adaption process or its mechanism are yet known. A diaphyseal fracture in a dog femur is generally considered clinically healed within a shorter period than 7 months when treated

INTRACARDIAL ARTERIOGRAPHIC STUDY ON VASCULAR CHANGES IN AMPUTATED RABBITS

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The vascular changes in rabbits after amputation were studied *in vivo* with arteriography after intracardial injection of contrast. In the amputated extremity an initial vasoconstriction of the arteries was found. Thereafter changes were observed in arteries and veins, both in the operated and contralateral extremities depending on the level of amputation and the manner in which the stump was closed. After amputation distally on the extremity and after stump closure without myoplasty arteriovenous shunting was observed in the amputation stump. Arteriovenous shunts were not seen after knee disarticulation and after proximal amputation on cruris with myoplasty. Inactivity of the muscles in the amputation stump is supposed to be the cause of the shunt formation. After mid femur amputation a permanent vasoconstriction of the femoral artery was observed whereas artery dilation was seen when amputation on the femur was combined with plugging of the medullary cavity.

Key words: amputation level, arteriovenous shunt, closure of the medullary cavity, intracardial arteriography, vascular changes in amputated rabbits.

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Previous studies of vascular changes which place after amputation have been based chiefly on arteriography. Increased vascularization in the amputation stump has been observed in both clinical and experimental investigations, but no unequivocal in the diameter of the related arteries has been demonstrated. Hulth & Olerud (1962) and Langhagel (1968) reported arterial diameters. Erikson & (1966) and Hansen Leth & Reimann (1972) observed transient dilation whilst Hasse et al (1960) and Erikson (1965) found in diameter. The reason for these vessel diameter is not clearly understood. Hasse et al suggested that reduced resulted from decreased blood circulation in the amputation stump whereas found no relationship between degree

of dilation and magnitude of blood flow. After amputation on rabbits Hansen Leth (1976) observed an increased muscle blood flow in the stump which was dependent on the level of amputation and on the manner in which the marrow cavity was closed.

In this experimental study *in vivo* arteriography on rabbits has been used to determine the vascular changes after amputation and to explain the way in which the amputation level and the method of stump closure influence the vascularization in the amputation stump.

MATERIAL AND METHODS

Thirty two adult rabbits, weighing 3-4 kg had their left hind leg amputated under Nembutal anaesthesia. In 21 animals amputation was



Figure 1 Arteriograms (a) Preoperatively, (b) immediately after fracture on the crus, and (c) immediately after subsequent amputation

performed on the crus, in 5 cases distally and in 16 proximally, at the level of the tibiofibular synostosis. In the proximally amputated animals the marrow cavity was left open in four and closed with myoplasty in seven and in a further five myoplasty was combined with osseous plugging of the marrow cavity. Disarticulation of the knee joint was carried out in six animals - three of these had been subjected to amputation of the crus prior to the disarticulation. Femur amputation was performed on eight animals, three with distal amputation without myoplasty - two of these had been subjected to amputation of the crus prior to amputation on the femur - and five with mid-thigh amputation, two with myoplastic closure and three with myoplasty combined with osseous plugging of the marrow cavity. In two animals the crura were fractured prior to amputation and the immediate arteriographic changes after fracture were investigated. Two animals died, unoperated, in relation to arteriography.

Arteriography was carried out while the animals were under Nembutal anaesthesia. The animals were placed supine on the AOT - film changer. Seventy-six per cent Urographin was injected intracardially with a lumbar needle (90 x 0.9 mm) inserted through the skin at the tip of the xiphoid process and thrust into the heart. The needle was kept open with heparin saline solution and a bolus of 8 cm³ contrast was injected manually during a period of 1-1.5 seconds. Six pictures were taken with one exposure every 2 seconds. These clearly portrayed the arterial and venous circulations, and permitted estimations of the flow rate (transit time). The degree of change in arterial diameter was measured on subtraction films at cor-

In all, 70 arteriographs were taken, seven preoperative and 63 within periods of from 1 hour to 130 days, postoperatively. One animal was arteriographed 8 times, one 6 times, two 4 times five 3 times, ten twice and thirteen once.

RESULTS

On the preoperative arteriographs only the larger arteries were contrast-filled, the crural arteries were thread-like, none or only a few veins were seen and vein filling was late in appearance.

Arteriographs immediately after amputation disclosed a vasospasm in the amputation stump in contrast to the vasodilation immediately after a closed fracture (Figure 1). Two or four days after amputation on the crus the arteries to the stump were seen to be dilated, dependent on the closure of the stump and the amputation level.

Table 1 illustrates the contrast passage through arteries and veins (transit time). Early appearance of veins were seen $\frac{1}{2}$ -1 week after distal amputation with myoplasty as well as after proximal crural amputation without myoplasty. This happened simultaneously with dilation of the arteries and there was a considerable formation of new vessels in the amputation stump. A similar dilation of arteries and rapid filling of veins occurred in the contralateral extremity (Figures 2, 3), but no contralateral vein filling was seen if a tourniquet was applied distally on the contralateral crus.

striped ruler placed across the pelvic area of the rabbit)



Figure 2 Arteriogram 2 seconds after the injection 32 days after amputation without myoplasty



Figure 3 The same rabbit as in Figure 2 Four seconds later Note the filling of the superficial veins

Table 1 The rate of contrast passage (transit time) in the arteries and veins in the amputation stump
One sign means one picture—2 seconds

TRANSIT-TIME

OPERATION	1 HOUR	1/2 WEEK	1 WEEK	2 3 WEEKS	4 5 WEEKS	6 7 WEEKS	>10 WEEKS
AMP DISTALLY ON CRUS	xxxxx	xxxxx	xxxxx	xx ooo	xx oooo	xxxxx	xxxxx ooooo
MYOPLASTY		xx ooo	xxx aa				
AMP PROX ON CRUS	xx	xxx	xx oooo	xx aaa	xx ooooo	xx oooo	
MYOPLASTY	xx	xx ooooo	xx aa		xx ooooo	xx ooooo	
AMP PROX ON CRUS	xx	xx	x	xx aaaa	xxxxx	xxxxx	
MYOPLASTY	xxx	xxx	xx	xx aaa			
AMP PROX ON CRUS	xx	xx	xxxxx	xxxxx oooo	xxx ooo	xx ooo	xxxxx
PLUGGING			xxx aaa		xx oo		xxxxx ooo
EXARTICULATIO GENU	xx	xx	xx aaa	xx aa xx a	xxxxx aa xxxxx aa		xxxxx
AMP DISTALLY ON FEMUR			xx ooo	xx ooo	xx oo	xx	xx ooo

x ARTERY OCCURRENCE

△ VEN SLIGHT OCCURRENCE

o VEN MODERATE OCCURRENCE

• VEN MARKED OCCURRENCE



Figure 4 Twenty days after amputation with myoplasty Six seconds after the injection

These findings indicate that arteriovenous shunting takes place in the amputation stump and distally in the contralateral extremity. After proximal crus amputation without myoplasty the arterial dilation and vein filling in the amputation stump reached a maximum 4-7 weeks after amputation (Table 1).

After proximal crus amputation with myoplasty a moderate arterial dilation was observed on the operated side, but only a few newly formed vessels appeared in the stump and 2-3 weeks after operation only a few veins were seen on the operated side (Figure 4). Following proximal crus amputation with myoplasty and osseous plugging of the marrow cavity a greater number of vessels appeared in the stump and dilation of



Figure 5 Eighty five days after amputation with osseous plugging and myoplasty. Twelve seconds after the injection. Note the filling of the deep veins on the left hind leg and superficial veins on the right.



Figure 6 Twenty five days after knee disarticulation. The pictures were unchanged throughout the arteriography

related arteries and appearance of veins was seen 2-3 weeks after operation. On the operated side the deep veins were observed and on the contralateral extremity the superficial veins (Figure 5).

After knee disarticulation there was reduced filling of the popliteal artery and of the distal part of the femoral artery on the operated side and only a few newly formed vessels appeared in the femur (Figure 6). When knee disarticulation was combined with resection of the distal femoral condyle with detachment of the muscle fixation and opening up of the marrow cavity (distal femur amputation without myoplasty), dilation of the femoral artery all the way to the tip of the amputation stump was observed after 1 week and the arterial blood



Figure 7 Twenty days after distal amputation on the femur Two seconds after the injection



Figure 8 Eighty days after amputation on the femur Four seconds after the injection



Figure 9 Thirty-five days after amputation on the femur combined with osseous plugging Note the abundance of arteries and veins compared with Figure 8

flow and the filling of veins were more rapid than after knee disarticulation (Figure 7)

After amputation at a more proximal level on the femur (Figure 8) the femoral artery on the operated side was occluded at the level of the hip joint, whilst it was dilated on the non-operated side. The arterial blood flow was slower than after distal femur amputation, vein filling was late in appearance and only a few veins were seen. However, when femur amputation was combined with plugging of the marrow cavity (Figure 9), a greater number of vessels appeared in the stump and dilation of related arteries and appearance of veins were seen.

DISCUSSION

After intracardial injection of contrast, serial arteriography provided a clear portrayal of the arterial and venous components of the blood circulation of amputated rabbits and by this method the investigation could be repeated at different time intervals on any one animal.

Earlier arteriographic investigations of amputated rabbits have not employed the serial exposure method, and the experimental animals were sacrificed in relation to the arteriographic investigations (Hulth & Olerud 1962, Hansen-Leth & Reumann 1972). Erikson & Olerud (1966) performed angiographies according to an experimental method described by Ekholm *et al* (1964).

The rabbits were intravenously injected with Thorotrast and a single exposure was used. This permitted the advantages of an *in vivo* study of circulatory changes, but the use of Thorotrast is prohibited nowadays. In these previous investigations the vascular changes in the amputated extremity were examined in relation to the opposite side. In the present study we found that vascular changes also occur in the contralateral extremity after amputation. This is in agreement with the findings of Hansen-Leth (1976) who, using the Xenon¹³³ clearance method, observed changes in the blood flow in the contralateral extremity, related to the amputation level and the treatment of the amputation stump.

The present investigation has shown that amputation of the crus, in contrast to closed fracture, provokes an initial constriction of the arteries to the amputation stump. This is in agreement with the findings of Erikson & Olerud (1966), who after crus amputation on rabbits with myoplasty observed an initial constriction of arteries and veins, which may be explained by an involuntarily provoked spasm. Similarly, measurement of muscle blood flow (Hansen-Leth 1976, 1977) revealed that amputation in rabbits caused an initial reduction in the flow in the amputation stump, whereas the flow in the triceps surae immediately after open fracture of the crus was unchanged.

Erikson & Olerud (1966) observed dilation of the arteries and veins in the amputated leg 3 days postoperatively. This dilation increased progressively and occasionally persisted for more than 4 months. The present investigation has shown that dilation of arteries and occurrence of veins depend on the amputation level and the method of stump closure. Dederich (1963) reported that when the marrow cavity was left open venous stasis occurred in the stump, but when closed myoplastically, venous return was improved. We found that crus amputation without myoplastic closure brought about abundant vein formation in the stump, whereas no veins appeared in the stump after amputation with myoplastic closure. However, the veins were seen to appear at the same time as the artery or immediately after, and veins appeared simultaneously with dilation of the related arteries and considerable formation of new vessels in the amputation stump. This means that the occurrence of veins must be due to arteriovenous shunts in the stump and not an expression of venous stasis. Erikson (1965) in a clinical investigation found that amputation without myoplastic closure in some cases led to formation of arteriovenous shunts. Similarly, Hulth & Olerud (1962) also proposed a shunt effect to be the reason for the more rapid vein filling in the amputated extremity observed after crus amputation in rabbits. Similar arteriographic appearances are seen after surgically produced arteriovenous fistulas (Kelly et al 1959, Holman 1968).

It has been demonstrated in the present study that arteriovenous shunting in the amputation stump, as well as in the contralateral extremity, is pronounced after crus amputation without myoplasty. The underlying cause could be the inactivity of the muscles in the stump. Occurrence of rapid vein filling in the stump was seen $\frac{1}{2}$ –1 week after amputation. Similarly Hulth & Olerud (1960) found arteriovenous shunting at the end of the first week after experimentally induced muscle inactivity. The proposal that the muscle inactivity is chiefly responsible for

the vascular changes is supported by a comparison of the results of knee disarticulation and femur amputation just proximal to the femoral condyle with release of the femoral muscles. After knee disarticulation the diameter of the femoral artery was reduced and only a few veins appeared, whereas after condyle resection the femoral artery was dilated all the way to the tip of the amputation stump, and there was a more rapid appearance and abundant filling of veins. However, the arteriovenous shunting after distal femur amputation is less than after amputation on the crus, and after amputation at the mid-femur level no signs of arteriovenous shunts were seen. The femoral artery was occluded at the point where it joins with the circumflex femoral arteries. Erikson (1965) also found that arteriovenous shunts appeared more frequently after crus amputation than after femur amputation and he observed a greater reduction in artery diameter after femur amputation than after amputation on the crus. Similarly, measurements of muscle blood flow (Hansen-Leth 1977) showed that femur amputation on the rabbit, in contrast to crus amputation caused no increase in blood flow in the amputation stump.

Amputation with myoplasty combined with osseous plugging of the marrow cavity in contrast to amputation with myoplastic closure alone, resulted in dilation of related arteries, an abundance of vessels in the stump and a greater occurrence of veins in both extremities, after crus amputation as well as after amputation on the femur. In a clinical study Langhagel (1968) found a greater number of arteries and veins in the amputation stump after osteomyoplastic closure than after myoplastic closure alone.

In previous studies the relationship between muscle blood flow and degree of dilation of related arteries in the stump after amputation is not clearly understood. Hasse et al (1960) concluded that reduced diameters in afferent arteries resulted from decreased blood flow whereas Erikson (1965) found no relationship between degree of dilation and

magnitude of blood flow. The present investigation shows that the dilation of supplying arteries to the stump resulted from the arteriovenous shunting, and that the degree of dilation cannot be assumed to be directly related to the magnitude of muscle blood flow. The increased shunting led to a poorer nutritive circulation in capillaries and minor vessels. Similarly, measurement of muscle blood flow after amputation on rabbits (Hansen-Leth 1976) revealed that myoplastic closure of the stump, preventing muscle inactivity and arteriovenous shunting, improved the muscle blood flow in the amputation stump.

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RADIOLOGICAL STUDIES OF THE WRIST JOINT AMONG CHAIN SAW OPERATING LUMBERJACKS IN JAPAN

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Radiological changes of the wrist joint among 580 chain saw operators and 90 forestry workers (control) who had never used vibratory tools have been studied. In both groups, degeneration in the distal radio-ulnar joint and the lunate bone was recorded as a prominent finding. However changes peculiar to chain saw operators or a close relation between those changes found and the number of years spent operating a chain saw could not be found in this study.

Key words: radiological study, wrist joint, chain saw operator, variant of the ulna

Accepted 14 XII 77

Throughout the world, recent technological developments have become the cause of various occupational disorders. In fact, even as early as 1911, there was a report by G. Longa on the relationship between vibratory tools and "white finger" (Miura 1975).

Since 1955, use of the chain saw among Japanese lumberjacks has increased steadily and is now common throughout the country. Furthermore, by 1963, the average number of hours which Japanese forestry workers spent daily operating a chain saw had reached five (Miura 1975). In 1970, in an effort to prevent vibration syndrome, this time was limited to 2 hours by National Forestry officials.

Radiological changes of the wrist joint among 580 chain saw operators and 90 controls have been under study since 1970.

METHOD

For this study, X-ray films of the 670 chain saw operators and controls were examined as shown in Table 1. Standard antero-posterior and lateral

exposures of the wrist joint (Kagita 1966) were collected at this clinic and then studied by the authors of this paper.

In grading radiological changes, the following numerical expressions were used, 0 mm mean normal, 1 corresponding to a slight change and 2 meaning a prominent change. The numerical designations of several items, such as bony atrophy, cyst formation, spur formation, narrowing of the joint space, anomaly or subchondral bony sclerosis, were summed up for each joint, the result being the grade of overall radiological degeneration.

RESULTS

The age distribution and years spent operating a chain saw were as shown in Table 1.

Variants of the ulna were detected in the antero-posterior view. If the longitudinal difference between the ulna and the radius in the distal radio-ulnar joint was less than 1 mm, the ulna was classified as a zero variant, if the difference was more than 1 mm, the longer ulna was ranked a plus

variant and the shorter ulna was designated as a minus variant. This definition was different from the usual one, as formulated by Hulthén (1935).

Of the 670 cases studied, 55.2 percent showed the zero variant, 43.7 percent a plus variant and 1.1 percent a minus variant. No differences were found between the right and the left wrist joints, as shown in Table 2.

Among the various changes recorded, arthrosis-like changes of the distal radio-ulnar joint were the most remarkable, followed by a cyst formation of the carpal bone, as shown in Figures 1 and 2.

Among the carpal bones, subchondral bony sclerosis and cystic changes were recorded most frequently in the lunate, then in the triquetrum and thirdly in the navicula, as shown in Figures 2 and 3. These changes were particularly common in chain saw operators under the age of 49 with a plus variant.

However, radiological changes of the wrist joint did not increase in accordance with the number of years spent operating chain saws, as shown in Figure 4.

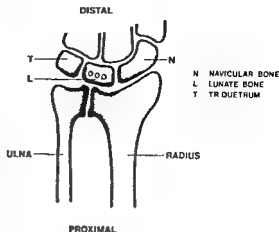


Figure 1 Illustration of radiological changes in A-P view of the wrist joint

DISCUSSION

Nowadays, Japanese forestry workers are mainly in their forties, fifties and sixties. Thus, in this study, age-related changes had to be analyzed along with the other radiological changes.

Table 1 Age distribution and number of years spent operating chain saws

Years of chain saw operation	Age	20-39	40-49	50-	Total
0-5		7	10	5	22
6-7		17	20	5	42
8-9		19	29	9	57
10-		126	228	105	459
Total		169	287	124	580
Control		20	43	27	90

Table 2 Variant of the ulna (percent in 670 persons)

Percent of the total (percent in 670 persons)					
Left	Right	Plus	Zero	Minus	Total
	Plus	34.4	7.7	0	42.1
	Zero	10.7	45.2	0.9	56.8
	Minus	0.2	0.6	0.3	1.1
	Total	45.3	53.5	1.2	100.0

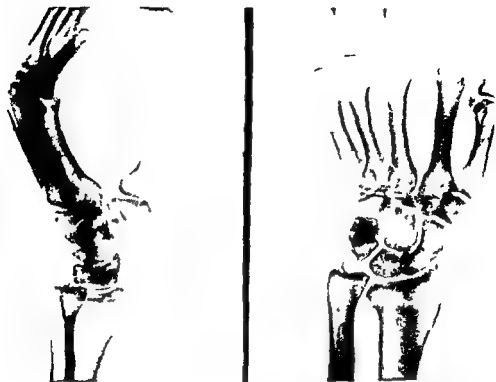


Figure 2 The wrist joint of a chain saw operator (plus variant of the ulna, cystic and sclerotic changes)

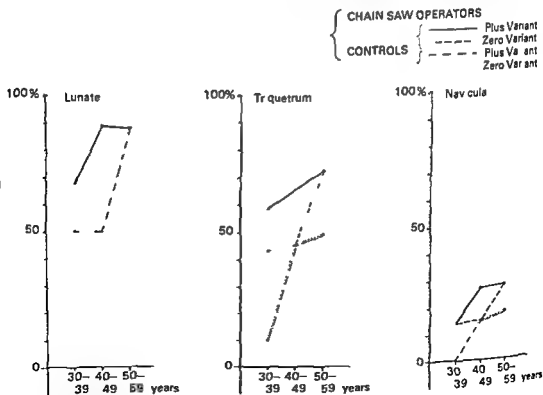
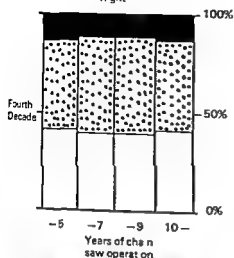
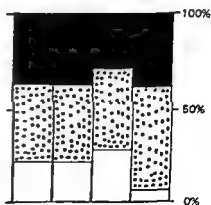
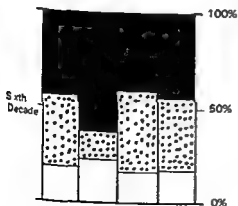
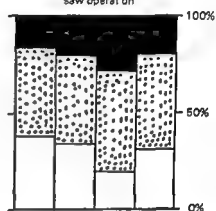
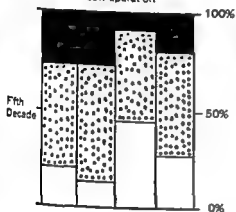
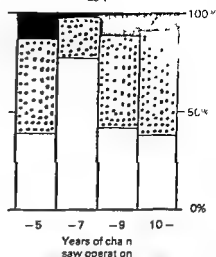


Figure 3 Relation between changes of the carpal bones and age

Right



Left



- Persons graded more than 8 points
- Persons graded 4 to 7 points
- Persons graded 0 to 3 points

Figure 4 Radiological changes in the wrist joint related to years of chain saw operation

As regards age-related changes in the wrist joints of Japanese forestry workers, degenerative changes in the distal radio-ulnar joint and the lunate bone were recorded as prominent findings

In previous radiological studies of the wrist joints of chain saw operators (Hellstrom & Andersen 1972 and James et al 1975), the existence of any special occupationally related changes could not be proven

Special changes among chain saw operators or a close relationship between those changes found and the number of years spent operating chain saws could not be found in this study

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PREDICTION OF SPIROMETRIC VALUES IN PATIENTS WITH SCOLIOSIS

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The prediction of normal spirometric values requires a measure of the non-deformed body height of scoliotic patients. The arm span method has been used for estimating the non-deformed body height in spite of the fact that

span/height ratio

Multiple regression equations including arm span and age as regressors were used to calculate the non-deformed body height in scoliotic patients.

height and predicted spirometric values that agreed closely with those obtained by the method using the degree of curvature of the spine. The two methods may be used alternatively. In accordance with earlier reports, the predicted spirometric values were underestimated when the measured body height was used.

Key words: scoliosis, spirometry

Accepted 8 III 78

In scoliosis it is important to evaluate the decrease in lung volumes and ventilatory function of the patients as compared with normal conditions. A difficulty is that body height is generally used in prediction formulas for spirometric values. It has been pointed out earlier by Bergofsky et al (1959), Hepper et al (1965), Lindh & Bjure (1975), and others that the scoliotic curvature tends to decrease the body height and so make the predicted normal values falsely low.

The most promising methods described for predicting normal spirometric values, cor-

responding to the non-deformed body height of scoliotic patients, seem to be the arm-span method (Hepper et al. 1965, Johnson & Westgate 1970) and the method of calculating height loss from the lateral curvature of the spine (Lindh & Bjure 1975).

The arm-span method requires the determination of the relationship between arm span and body height of a non-scoliotic reference group. Arm-span/height ratios have been determined for several groups of both sexes (cf Hepper et al 1965), but few examinations seem to cover children. In general,

there seems to be a difference between sexes but conflicting results are reported, particularly with regard to children (Engelbach 1932, Hepper et al 1965, Johnson & Westgate 1970)

The present study was undertaken to examine the arm-span/height relationships of a homogeneously examined Swedish reference group covering both sexes and a wide age range, the purpose being to minimize the error of determining the corrected, non-deformed, body height and the predicted normal spirometric values of scoliotic subjects or subjects with other deformities affecting body height. Further, it was of interest to compare this method of prediction with the method of Lindh & Bjure (1975) calculating height loss from the lateral curvature of the spine of scoliotic subjects

MATERIAL

A reference group, 91 males and 118 females age range 5-78 years, and mean age 28 years in both groups, with normal body stature at inspection were used for establishing the normal relationships between arm span and body height

Twenty five patients, 21 females and 4 males with idiopathic scoliosis of varying degree were included in this investigation. They were between 11 and 25 years of age. The vertex of the primary curve of the scoliosis was localized in the thoracic spine. The Cobb angle of the primary curvature was 42 (12-82) degrees (mean and range)

METHODS

Arm span was measured on the standing subjects as the distance between the tips of the middle fingers of the maximally extended horizontal arms to the nearest tenth of a centimetre. This was done by means of a special device designed for the purpose (Figure 1). The arrangement ensures that the finger tips are at the same horizontal level during the measurements. The error of the method calculated from 19 (12 normal and 7 scoliotic subjects) duplicate measurements performed by different investigators with an interval of 6 hours to 2 days was 0.2 per cent (coefficient of variation of a single measurement). Body height was measured to the nearest tenth of

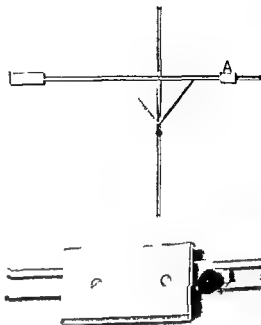


Figure 1 Device for measurement of arm span. The level of the horizontal bar can be adjusted to the height of the subject. The enlargement shows the part (A) that can be moved along the millimetre scale on the horizontal bar.

a centimetre on the barefooted subject standing upright

The angulation of the primary curvature of the scoliotic subjects was measured on frontal roentgenograms according to Cobb (1948). The body height loss of the scoliotic patients was calculated from the angulation of the primary curvature (angle of Cobb) according to the equation given by Lindh & Bjure (1975)

$$\log Y = 0.011 X - 0.177, R = 0.94 \text{ (Eqn. 1)}$$

where Y is trunk height loss (cm) and X is the angulation of the curvature (angle of Cobb in degrees). The equation is valid for Cobb angles < 100 degrees (Lindh & Bjure 1975).

Vital capacity (VC) and maximum voluntary ventilation (MVV₆₀ and MVV_F) were measured using a Bernstein spirometer (Bernstein et al 1957). Normal values were predicted according to

Statistical calculations Regression equations were calculated according to the method of least squares. Differences between means were tested using the *t* test (Snedecor 1956).

RESULTS

The mean arm-span/height (AS/H) ratio of the male reference group, 1 029, differed significantly from that of the female reference group, 1 012 ($P < 0.001$). Our results also indicate that the AS/H ratio in children is lower than in adults. The relation between AS/H ratio and age for males and females is shown in Figure 2. The regression equation for males was

$$AS/H = 1.013 + 0.000556 A, \\ S_y = 0.0215, R = 0.45 \text{ (Eqn 2)}$$

and for females

$$AS/H = 0.994 + 0.000660 A, \\ S_y = 0.0233, R = 0.45 \text{ (Eqn 3)}$$

The regression coefficients for age are statistically significant ($P < 0.001$). S_y is the residual standard deviation.

Figure 2 indicates that the relationships are quite linear within the whole age range, 5–78 years.

Equations 2 and 3 make possible a calculation of height from arm span. However, we

found it more suitable to calculate height directly from linear multiple regression equations relating height (H cm) (regressand) to arm span (AS cm) and age (A years) (regressors).

The equations were for males ($n=91$)

$$H = 0.9329^{***} AS - 0.0732^{**} A + 8.64, \\ S_y = 3.51, R = 0.98 \text{ (Eqn 4)}$$

and for females ($n=118$)

$$H = 0.9405^{***} AS - 0.0846^{***} A + 9.88, \\ S_y = 3.60, R = 0.97 \text{ (Eqn 5)}$$

The regression coefficients of equations 4 and 5 were statistically significant (***) indicates $P < 0.001$, ** $0.001 < P < 0.01$). Equations 4 and 5 were used to calculate the corrected body height from arm span in the scoliosis patients (cf also Appendix). Division into age classes or use of non-linear statistical models did not appreciably improve the accuracy of prediction of body height.

Prediction of spirometric values

The uncorrected measured body height, the body height calculated from arm span according to equations 4 and 5, and the body height corrected with the aid of equation 1 (Cobb-angle method) were used in the equations for calculating predicted normal values for vital capacity and maximum voluntary ventilation of scoliotic patients.

A comparison between the two methods of calculating the corrected body height of the 25 scoliotic patients, i.e., that using the arm-span measurement and that using the Cobb angle, is shown in Figure 3. The corrected body height obtained with the two methods agreed closely but was on average slightly smaller with the Cobb-angle method (mean difference 0.4 per cent or 0.7 cm). This is reflected in the predicted normal values for vital capacity and maximum voluntary ventilation obtained with the two sets of data (Table 1).

The scoliotic patients were divided into two groups. Nine patients with Cobb angles of 50 degrees or more (mean $61^\circ 9$, range

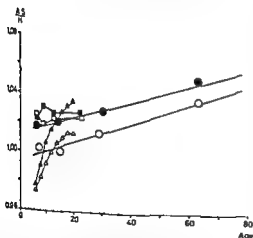


Figure 2 Arm span/height (AS/H) ratio in relation to age (years) for males ●—● and females, ○—○ (cf Eqns 2 and 3). The symbols indicate mean values for age groups 5–9, 10–19, 20–49 and 50–79 years. Males and females from Engelbach's material are symbolized by ▲—▲ and △—△, respectively, and corresponding groups from Johnson & Westgate's study by ■—■ and □—□.

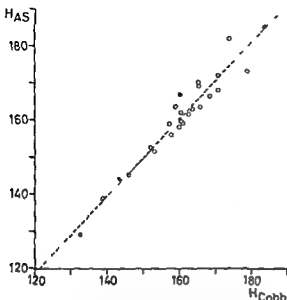


Figure 3 Body height (cm) of 25 scoliotic patients corrected by the method of Lindh & Bjure (1975), H_{Cobb} , and by Eqns 4 and 5 of the present paper, H_{AS} . ● = males, ○ = females. The thin continuous line is the identity line. The dotted line corresponds to the linear regression equation fitting the results, $H_{AS} = 1.052 H_{Cobb} - 7.65$, $S_y = 3.29$, $R = 0.97$.

53–82°) formed group A, and 16 patients with an angle of less than 50 degrees (mean 30° 9, range 12–46°) formed group II. In both groups the mean values of vital capacity and maximum voluntary ventilation in per cent of predicted normal values were almost the same with the Cobb-angle method and the arm-span method of correction. Higher spirometric values in per cent of predicted normal values were obtained when using the uncorrected body height than when using the body height predicted from the arm-span or the Cobb-angle method ($P < 0.01$).

DISCUSSION

In conformity with earlier authors, the results indicate that the use of measured body height for predicting lung volumes and ventilatory capacity in scoliotic patients gives an underestimate of the functional disturbance. A

Table 1 Vital capacity and maximum voluntary ventilation in per cent of predicted normal values (VC% and MVV%) of two groups of scoliotic patients

	Group A <i>n</i> = 9	Group B <i>n</i> = 16
VC%, calculated from		
Measured H	79	80
H corrected by the Cobb-angle method	75	78
H calculated from arm span	75	77
MVV%, calculated from		
Measured H	86	85
H corrected by the Cobb-angle method	83	81
H calculated from arm span	83	81
MVV_F%, calculated from		
Measured H	80	77
H corrected by the Cobb-angle method	77	75
H calculated from arm span	77	74

In group A the Cobb angle of the primary curvature was > 50 (53–82) degrees, in group B it was < 50 (12–46) degrees, mean (range). The normal values of VC and MVV were calculated according to Berghlund et al (1963), Birath et al (1963) and Grimby & Soderholm (1963) for adults, and according to Bjure (1963) for children using (1) the measured standing body height (H), (2) H corrected according to Lindh & Bjure (1975), and (3) H calculated from arm span (Eqns 4 and 5).

correction of the body height is therefore warranted.

The arm-span method of estimating the non-deformed body height of scoliotic patients has had the disadvantage that the relationship between arm span and body height has not been well defined. Some earlier investigators have reported different arm-span/height ratios for males and females (Hepper et al 1965) as well as for different age groups (Engelbach 1932). Some investigators use the same arm-span/height ratio independent of age (Hepper et al 1965), while the results of Johnson & Westgate (1970) indicate that the arm-span/height ratio is independent of both age and sex.

Divergences of opinion with regard to the arm span/height ratio seem to be particularly large for the younger age groups (below 20 years of age). These age groups are particularly important, because they correspond to the ages in which idiopathic scoliosis most frequently first appears. However, the reference group covers a wider age range and makes the arm span method applicable also in the case of body deformities affecting older subjects.

Our results for the arm-span/height ratio fall between those of Johnson & Westgate (1970) and Engelbach (1932) (see Figure 2). Differences in the populations and the time periods of collecting the data indicate that racial differences or secular changes have contributed to the different results of the examinations.

Our results for the age groups above 19 years of age agree fairly well with those of Hepper et al. (1965), although these authors assume that the arm span/height ratio is independent of age. We have preferred linear multiple regression equations which include the effect of age and sex, in predicting corrected body height from arm span.

When applied to scoliotic subjects the method based on arm span for correcting body height might be expected to result in a slight underestimation of corrected height for the following reasons

- (1) Because of their scoliosis the scoliotic patients might not hold their shoulders at the same horizontal level during the measurements of arm span. This may result in a falsely low value for arm span. Thus, if a line through the shoulder joints has a 20 degree angle to the horizontal the arm span will be diminished by about 16 per cent, assuming a ratio shoulder (biacromial) width/arm span of 0.21. In most cases the error should be less and thus possible divergence from normal arm span caused by the deformity is not large and may be disregarded (cf Hepper et al 1965).

- (2) According to Burwell et al. (1977) patients with idiopathic scoliosis have an abnormality of general skeletal growth affecting the trunk and the upper limbs. The biacromial width may be small and the upper limbs may be short, particularly on the concave side of the primary spinal curve, in relation to, for example, subischial height. However the relative reduction in arm span due to such a growth abnormality seems to be small.

The good agreement between the corrected body height obtained with the arm-span and the Cobb-angle methods indicates that the possible underestimation of corrected body height by the arm-span method is small at least in the range of moderate scoliosis examined. Inherent uncertainties of the Cobb-angle method must also be considered.

The advantages of the arm-span method are that the measurements can easily be made at the same time as the spirometry and they are not influenced by other factors which may also diminish height (e.g., additional curvatures or malformation of the spine, abnormally short legs or amputated legs). The body height calculated by means of the arm-span method may therefore be advantageously used in several types of body stature deformation for prediction of normal values of lung function tests.

The comparatively small difference (in the order of 3-4 per cent in group A) between vital capacity and maximum voluntary ventilation in per cent of values predicted from measured body height and corrected body height by the arm span or the Cobb-angle method, in our group of scoliotic patients, and those obtained by, for example, Hepper et al (1965) and Johnson & Westgate (1970), is explained by the smaller scoliotic curvatures in our group. The results agree with those of Sevastikoglou et al (1976). It is therefore particularly important to use the non-deformed body height for prediction of normal spirometric values in cases of severe scoliosis.

APPENDIX

Tables for predicting body height (cm) from arm span, AS (cm) and age, A (years) from Eqns. 4 and 5 for males and females.

AS	A	5	10	20	40	60	80
Males							
100		102	101				
105		106	106				
110		111	111				
115		116	115	115			
120		120	120	119			
125		125	125	124			
130		130	129	129			
135		134	134	133			
140		139	139	138			
145		144	143	143	141	140	138
150		148	148	147	146	144	143
155		153	153	152	150	149	148
160		158	157	156	155	154	152
165		162	162	161	160	158	157
170		167	167	166	164	163	162
175			171	170	169	168	166
180			176	175	174	172	171
185			181	180	178	177	176
190			185	184	183	182	180
195			190	189	188	186	185
200				194	192	191	190
Females							
100		104	103				
105		108	108				
110		113	112	112			
115		118	117	116			
120		122	122	121			
125		127	127	126			
130		132	131	130			
135		136	136	135			
140		141	141	140	138	136	135
145		146	145	145	143	141	139
150		151	150	149	148	146	144
155		155	155	154	152	151	149
160		160	160	159	157	155	154
165			164	163	162	160	158
170			169	168	166	165	163
175			174	173	171	169	168
180			178	177	176	174	172

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SACROCCOCCYGEAL AGENESIS

A Report of Four New Cases

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A total of 188 cases of sacral agenesis reported in the English literature are reviewed, and four new cases added. In 112 cases where the sex was given 60 were males (53 per cent) and 52 were females (47 per cent). In 163 cases where clinical details were available, 47 children (26 per cent) had unilateral or bilateral dislocation of the hips, 77 (49 per cent) had unilateral or bilateral club feet and 23 children (17 per cent) had spina bifida deformities. Comments are made on the aetiology, the clinical picture and the management.

Key words: agenesis, agenesis, lumbosacral, sacroccoccygeal, sacrum.

Accepted 14 x 77

Sacral agenesis was first described by Hohl in 1852. Further cases have been reported sporadically in the English literature, many describing accompanying musculoskeletal and visceral abnormalities.

The aim of this paper is to add a further four cases and to analyse the incidence of accompanying malformations. Comments are made on the relation of the condition to maternal diabetes, the clinical picture and the aims of management. Table 1 records chronologically the previously reported cases, the sex and the accompanying congenital malformations.

CASE REPORTS

Case 1 A baby girl (T.D.) was born on 7.5.73 to healthy parents, there being no family history of diabetes.

She was noted to have a barrel-shaped chest, atrophic calves and bilateral club-feet (Figure 1). Radiographs (Figure 2) demonstrated absence of the fourth and fifth lumbar vertebrae, sacral

agenesis and congenital dislocation of the right hip.

Her club-feet were treated by strapping for 6 weeks and at the age of 4 years they are normal. The congenital dislocation of the right hip was treated initially by an Aberdeen splint, but it did not reduce. Open reduction and de-rotation osteotomy were performed at the age of 18 months followed by a Salter's osteotomy at the age of 3½ years. At the age of 4 years she walks with a slight limp. She is continent of faeces but still suffers from precipitancy of micturition. She attends a normal school.

Case 2 A baby girl (S.M.) was born on 28.5.73 to healthy parents; the mother had no previous miscarriages. There were no virus infections during the pregnancy and there was no history of diabetes in the family.

She was noted to have bilateral dislocation of the hips and bilateral club-feet with marked atrophy of both calves.

Radiographs (Figure 3) demonstrated sacral agenesis, absent of the fifth lumbar vertebra and spina bifida of the fourth lumbar vertebra. The lumbar spine was interposed between the two iliac bones to replace the absent sacrum. An intravenous pyelogram (IVP) examination showed a single pelvic kidney.

Treatment of the club-feet and congenital dis-

Table 1 Cases of sacral agenesis reported, the sex and the accompanying congenital malformations

Year	Author	No of cases	Sex	CDH bilat or unilat	TEV bilat or unilat	Spina bifida	Visceral abnormalities
1852	Hohl	1					
1859	Wertheim	1					
1884	Lutzman	1	F				
1889	Albert	1					
1910	Mally	1		1	1		
1910	Friedel	1			1		
1910	Fitch	1					
1911	White	1			1	1	
1913	Charlier & Sauts	1					
1913	Rendy	1		1	1		
1921	Elmslie	1	M	1	1		
1923	Bradburn	1					
1924	Stewart	1			1		
1924	Desfosses & Mouchet	1			1		
1924	Foix & Hilleman	1					
1925	Leri & Linossier	1	F		1		
1927	Drehmann	1			1		
1929	Brack	1					
1931	Feller & Srwenbern	1			1	1	
			- M	1	1		
1935	Hamsa	2<	- M	1			
			- F		1		
1935	Girard	1					
1935	Barros Lima	1					
1935	Keinbock & Zinner	1					
1936	Arauzo	1					
1936	Lamoot & Graux	1	F				
1936	Muller	1	M	1	1		
1937	Hilgenreiner	1		1	1		
			- M				
1938	Pouzet	2<	- M	1	1		
			- ?				
1940	Zeligs	2<	- F		1		
1941	Feller & Sternberg	1			1		
1945	Berman	1	F				
1947	Litcher	1	F		1	1	
1950	Freeman	1	M				
			- F				
1951	Del Duca et al	2<	M	1	1		
1953	Katz	1	M		1		
1953	Soothill	1	M		1		
1957	Williams & Nixon	51		1	5		43
			- M		1		
1957	Pirkey & Purcell	2<	- M		1		
			M 27				
1959	Blumel et al	50<	F 23	18	27	14	8
1961	Dassel	1	F		1		

Table 1—cont

Year	Author	No of cases	Sex	CDH bilat or unilat.	TEV bilat or unilat	Spina bifida	Visceral abnormalities
1963	Russell & Atken	5	F 1 M 4				
1967	Frantz & Atken	3			3		
1969	Banta & Nichols	7	F 4 M 3	4	4	1	
1971	Rosenfelder	24	F 12 M 12	8	12	8	
1976	Abraham	1	M	1	1		
1977	Dounis	4	F 3 M 1	3	4	2	2

location of the hips was abandoned after 2 months because of severe mental retardation. The patient remains in a hospital for mentally subnormal children.

Case 3 A boy (A.E.) was born on 14.4.68 to healthy parents. The mother did not suffer from any virus infections during the pregnancy and there was no history of diabetes in the family. The child was born with severe kyphoscoliosis, bilateral club-feet and flail legs. Radiographs demonstrated sacral agenesis, multiple hemivertebrae and subluxation at the left hip. The exact level of the agenesis was impossible to determine because of the kyphoscoliosis and pelvic tilt. An IVP demonstrated fused kidneys.

All attempts at corrective treatment were

abandoned after a short time because of the flail legs. Although incontinent of urine and faeces he attends normal school and manages using a wheelchair and orthotic devices.

Case 4 A baby girl (J.M.) was born on 3.8.71 to healthy parents with no family history of diabetes. She attended an orthopaedic clinic at the age of 5 years, having suffered progressive cavovarus deformity of both feet over a period of 2 years. She was noted to have atrophy of both calves and radiographs demonstrated sacral agenesis below the level of the second sacral vertebra (Figure 4). At the present time she is undergoing surgery for correction of foot deformities.

DISCUSSION

There have been a number of theories concerning the aetiology of malformations and absence of the caudal part of the spine. A family history has been reported in only one case, a father and son (Pouzet 1938). Maternal diabetes may also be a significant aetiological factor. In the 192 cases described in the literature, 16 diabetic mothers have been reported (8.33 per cent), and this incidence may be even higher as many did not record the health of the parents.

It has further been suggested that insulin injections may have a teratogenic effect on the embryo. This view has been supported by



Figure 1 Barrel shape chest and atrophic calves (Case 1)



Figure 2 Absence of the lower two lumbar vertebrae and sacrum with apposition of the iliac bones (Case 1)

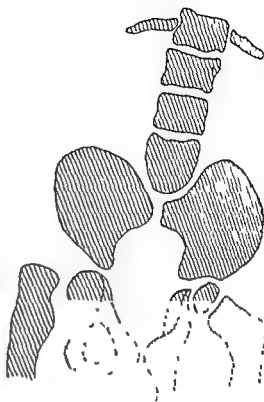
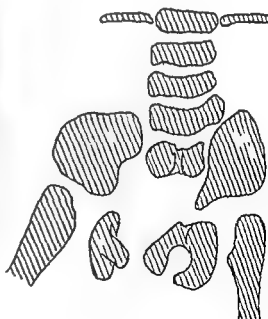


Figure 3 Spina bifida of the fourth lumbar vertebra and absence of the sacrum and fifth lumbar vertebra. The lumbar spine is interposed between the iliac bones (Case 2)



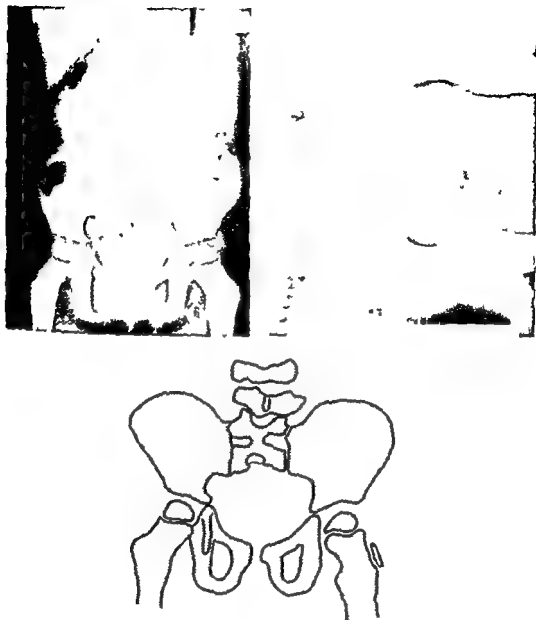


Figure 4 X-ray and tomography show partial absence of the sacrum (Case 4)

Duraiswami (1950) who has experimentally produced caudal depression in chickens by injecting insulin into the eggs. He excluded trauma as a cause, since inactivate insulin or normal saline injections produced no deformity.

The typical clinical picture is of a child with a barrel-shaped chest contrasting with

narrow and flattened buttocks and shortened intergluteal cleft. The lumbar lordosis is normally absent, although there may be prominence of the lower lumbar spine (Figure 1). The legs are cone-shaped due to atrophic or absent calf muscles. The pelvic ring is completed with either direct apposition of the iliac bones or with interposition of the lum-

bar spine replacing the absent sacrum (Figures 2, 3) Scoliosis occasionally occurs and in some cases, paralytic or due to hemivertebrae Visceral abnormalities such as anal atresia, fused kidneys and congenital heart malformations are not uncommon

The management of these cases is symptomatic for each system, and the treatment should start as soon as possible

ACKNOWLEDGEMENTS

The author is indebted to Mr. H. P. D. G. for the

manuscript

recting it

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PROCEEDINGS OF THE FINNISH ORTHOPAEDIC ASSOCIATION

Helsinki, Finland, November 12, 1977

EDITOR A. ALHO

THE HISTORY OF TREATMENT OF CONGENITAL DISLOCATION OF THE HIP JOINT IN FINLAND

Fabian Langenskiöld Lecture

L. E. Laurent

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Helsinki

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Seppo Autio

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Medical care in Finland is carried out at three levels (1) the basic level (local health centres, etc.), (2) the intermediate level (central hospitals), (3) the highest level (university hospitals). The role of the local centres in the care of cerebral palsy (CP) patients concerns early diagnosis and supportive treatment at home. The role of the central hospitals involves more advanced follow-up and treatment on an outpatient basis. The university hospitals see to ward treatment (rehabilitation units) and special examinations and treatment, including orthopaedics. At present, there are rehabilitation units in Helsinki and Kuopio.

The consideration of an orthopaedic procedure involves several factors, such as, mental function, developmental stage, treatment of other disturbances (e.g., speech disorders), the nature and severity of the motor abnormality and, especially, adequate scope for preoperative and postoperative treatment. Because a competent team is required in such a consideration, and because a sufficient number of cases is needed to get adequate experience, it is suggested that operations be performed in two or three centres (Helsinki, Kuopio, Oulu). The operations should be performed by orthopaedic surgeons in centres with facilities for proper preoperative and postoperative treatment.

THE NEUROLOGICAL MECHANISM OF SPASTICITY

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CP syndromes can be classified as follows: *Spastic forms* (hemiplegia, "double" hemiplegia, tetraplegia or quadriplegia, and diplegia), *Extrapyramidal forms* (dyskinetic type, dystonic type, ataxia, and tremor), *Mixed forms* (primarily spastic and primarily extrapyramidal).

Orthopaedic treatment is mainly indicated in the spastic forms, which make up 60-80 per cent of CP syndromes.

The basis of spasticity is a UMN lesion leading to a disturbance in the inhibitory and facilitatory system which normally regulates the muscular tonus via the α and γ neurone system at the muscular-spinal level. This disturbance is followed by a muscular imbalance. In the lower limb the spasticity is manifested in the extensor muscles, the plantar flexors of the ankle and toes being physiologically extensors, and in the adductors of the hip. In the upper limb the spasticity appears in the adductors of the shoulder, the flexors of the elbow, wrist and fingers, and the pronators of the forearm. From the orthopaedic point of view it is important to keep in mind that one cannot essentially change the basic disturbance by a peripheral operation. However, one can improve the motor function of a limb by changing the muscular imbalance and by making more normal patterns of movement possible.

THE SCOPE OF PHYSIOTHERAPY IN THE TREATMENT OF CP

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When brain damage is diagnosed or even strongly suspected in a newborn or older child

bar spine replacing the absent sacrum (Figures 2, 3) Scoliosis occasionally occurs and is, in some cases, paralytic or due to hemivertebrae Visceral abnormalities such as anal atresia, fused kidneys and congenital heart malformations are not uncommon

The management of these cases is symptomatic for each system, and the treatment should start as soon as possible.

ACKNOWLEDGEMENTS

I am indebted to Mr. H. D. G. M. for his help in the preparation of this paper. I am also indebted to Mr. H. D. G. M. for his help in the preparation of this paper.

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THE EFFECT OF 1α -HYDROXYCHOLECALCIFEROL ON THE HEALING OF EXPERIMENTAL FRACTURES IN ADULT RATS

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Unilateral tibial fractures were produced in adult, 1 year-old, male Sprague-Dawley rats. The animals were then treated for 8 weeks with daily doses of 2.5 μ g, 1.25 μ g or 0.125 μ g 1α -hydroxycholecalciferol (1α -OH-D₃). The aim of the investigation was to study the effect of this treatment on the healing

The healing rate of the fractures increased in all treatment groups compared with the controls. The water content of the fractured tibias increased in the rats treated with 2.5 μ g doses but decreased in the other groups. On the other hand the mineral content increased in the groups treated with 1.25 μ g and 0.125 μ g doses and decreased in the largest dose group. Furthermore the amount of organic material per wet weight increased with the 2.5 μ g dose and was mainly unchanged in the other groups. The hydrated bone density and the cortical thickness of the tibia increased most significantly in the group treated with 0.125 μ g but the trabecular bone area of the periosteal callus did not increase significantly.

The conclusion is drawn that treatment with small doses of 1α -OH-D₃ has a beneficial effect on the healing rate and on the mineralization of the fracture callus, and on cortical bone formation.

Key words: fracture healing, experimental 1α -hydroxycholecalciferol

Accepted 31 III 78

Therapeutic doses of Vitamin D promote calcification of bone in rickets and osteomalacia but Compere et al (1939) found that treatment with physiological doses of Vitamin D did not exert any stimulating effect on the osteogenesis or the mineralization of callus in experimental fractures. Beneficial effects of Vitamin D on fracture healing have, however, been reported in other studies (Bors

1927, Collazo et al 1930). Moreover, Vitamin D has been found to stimulate the differentiation of the osteogenic cell layer of the periosteum of the radius in adult guinea-pigs during fracture healing (Grauer 1932). Vitamin D was also found to display a special selective effect on the organic phase of bone healing in rats (Udupa & Prasad 1963) and on the mineralization of autogenous bone grafts in rabbits (Donatelli et al 1962) and further to accelerate the initial mineralization in fracture repair of rats (Steier et al 1967).

Supported by a grant from the Karolinska Institute

Great advances in the research of the biological functions and metabolism of Vitamin D have taken place in recent years. Thus, Vitamin D₃ is known to be hydroxylated in the liver to 25-hydroxycholecalciferol (Ponchon & DeLuca 1969) and further in the kidney to the metabolically active form 1,25-dihydroxycholecalciferol (Fraser & Kodicek 1970). The synthetic analog 1 α -hydroxycholecalciferol (Holick et al 1973) which is converted to 1,25-dihydroxycholecalciferol in the organism (DeLuca et al 1976) has been found to increase the intestinal absorption of calcium (Peacock et al 1974) and thus secondarily affect bone resorption (Raisz et al 1972) and remodelling.

Because the observations made in previous studies on the effect of Vitamin D are inconclusive, and because the dose-related effects of Vitamin D on fracture healing have not been thoroughly examined, the present investigation was undertaken to study the effect of various doses of the synthetic drug 1 α -OH-D₃ on healing of experimental fractures in adult rats.

MATERIAL

Altogether 75 male adult rats of the Sprague-Dawley strain were used in two different series. The rats were about 1-year-old. The initial body weight of the animals in the first series was 473 g in the second 538 g. All rats received a diet containing about 1.15 per cent calcium, 0.8 per cent phosphorus, and 24.5 per cent protein per dry weight. The diet contains an adequate amount of Vitamin D, i.e. 15 IU Vitamin D₃/10 g diet. The animals received food and water *ad libitum*.

Five days a week the rats received peroral doses of 1 α -OH-D₃ diluted in propylenglycol*. The administration of the drug was started after the tibia and fibula were fractured and continued for 6 weeks, after which the animals were sacrificed.

The first series comprised 30 rats. Thirteen were treated with 2.5 μ g 1 α -OH-D₃/day which corresponds to a dose of approximately 5 μ g/kg body weight. The remaining animals were used as untreated controls.

The second series comprised 45 rats. Fifteen

rats were treated with 1.25 μ g and another fifteen with 0.125 μ g 1 α -OH-D₃/day which corresponds to doses of 2.5 μ g and 0.25 μ g/kg body weight, respectively. The remaining animals in this series were used as controls.

METHODS

The final body weights of all rats were recorded. Seventy-two hours before killing 50 mg of Terramycin* was injected into each animal intraperitoneally. The rats were sacrificed by bleeding from the femoral artery under ether anaesthesia. Blood was drawn for determination of total serum calcium. The consolidation of the fracture was tested manually. The right fractured tibia was cleaned from the surrounding soft tissues and was subjected to various analyses. Roentgenograms were taken, and the 'tibia score' representing the cortical bone thickness was measured on the mid shaft of the tibia. The whole fractured tibia including the fracture area and the periosteal callus lump was used for determination of wet and dry weights, hydrated bone density and total ash content according to methods previously described and used in the laboratory (Sevastikoglou 1972).

Five fractured tibias from each group were prepared for histological microradiographic and fluorescence labelling analyses. The histologic samples were stained with haematoxylin-eosin and cut into 7 μ thick sections after decalcification. The microradiographs were prepared after embedding in methylmethacrylate and sawing off about 80 μ thick slices. These samples were also examined for fluorescence labelling under UV-light in a Zeiss microscope. For quantitation of trabecular bone mass of the periosteal callus a Zeiss image auto-analyzer was used.

The significance of observed differences was computed using the *t* test for non paired experiments.

RESULTS

No rats died during the experiment. The oral administration of the drug succeeded without difficulty.

The final body weight of rats treated with 2.5 μ g 1 α -OH-D₃ showed a significant decrease ($P < 0.001$) as compared with their initial body weight and with the final weight of the other rats in this series, which did not change significantly (Table 1).

The consolidation of the fracture, tested

* Kindly supplied by Loven Ltd Copenhagen, Denmark.

Table 1 Final body weight and serum calcium level in rats treated over a period of 6 weeks with 2.5 µg 1.25 µg and 0.125 µg 1α-OH-D₃/day, respectively

	Series I		Series II		
	Control rats	Experimental rats (2.5 µg 1α-OH-D ₃)	Control rats	Experimental rats (1.25 µg 1α-OH-D ₃)	Experimental rats (0.125 µg 1α-OH-D ₃)
Final body weight (g)					
n	17	13	15	15	15
̄y	492	403	535	540	555
sy	23	61	63	15	36
P	—	<0.001	—	> 0.05	> 0.05
Serum calcium mmol/l					
n	8	8	10	10	10
̄y	2.52	3.25	2.63	2.92	2.68
sy	0.06	0.01	0.08	0.12	0.67
P	—	<0.001	—	<0.001	> 0.05

manually at the end of the experiment, gave the following results: in rats treated with 2.5 µg 1α-OH-D₃, the fracture was stable in 6/13 cases and in the control rats in 3/17 cases. In rats treated with 1.25 µg, 7/15, and those treated with 0.125 µg, 6/15 fractures were stable. In the control rats of both treated series stable fractures were found in 4/15 cases.

The total serum calcium was significantly increased ($P < 0.001$) in rats treated with 2.5 µg and 1.25 µg 1α-OH-D₃, while no significant increase in serum calcium was observed in rats treated with 0.125 µg 1α-OH-D₃, as compared with the corresponding values from the control groups of animals (Table 1).

The wet weight of the fractured tibia including the callus lump increased in all treated rats, but the increase was significant ($P < 0.01$) only in rats treated with 2.5 µg of 1α-OH-D₃ (Tables 2 and 3).

The dry weight of the fractured tibia increased in all treated rats as compared with the controls. A significant increase ($P < 0.05$) was found in rats treated with 0.125 µg of 1α-OH-D₃ (Tables 2 and 3).

The hydrated bone density of the fractured

tibia increased significantly ($P < 0.05$) in rats treated with 1.25 µg and 0.125 µg 1α-OH-D₃, respectively (Tables 2 and 3).

The total ash content of the fractured tibia increased in all treated rats. The increase was significant ($P < 0.01$) in the rats treated with 0.125 µg of 1α-OH-D₃ (Tables 2 and 3).

The "tibia score" increased in all treated rats as compared with the controls. The increase was significant ($P < 0.05$) in rats treated with 2.5 µg and 0.125 µg 1α-OH-D₃, respectively (Tables 2 and 3).

The trabecular bone area of the periosteal callus showed an increase, though not significant, in rats treated with 0.125 µg 1α-OH-D₃, as compared with the controls. The values from rats in the other groups decreased. The differences were non significant (Tables 2, 3 and Figure 1).

The histological appearance of the callus from rats of different treatment groups and the controls showed no qualitative differences.

The fluorescence labelling of the osseous callus did not differ between the animals from the various treatment groups and the controls.

Table 2 Parameters of fractured tibia in rats treated over a period of 6 weeks with 25 μ g of 1 α -OH-D₃/day

Series I			
Fractured tibia		Control rats	Experimental rats (25 μ g 1 α -OH-D ₃)
Wet weight (g)	n	12	8
	y	1 0620	1 3050
	sy	0 1140	0 1940
	P	—	<0 01
Dry weight (g)	n	12	8
	y	0 7910	0 9130
	sy	0 0560	0 1350
	P	—	>0 05
Hydrated bone density (w/v)	n	12	8
	y	1 5146	1 4723
	sy	0 0460	0 0430
	P	—	>0 05
Total ash content (g)	n	12	8
	y	0 5282	0 5796
	sy	0 0428	0 0807
	P	—	>0 05
'Tibia score' (%)	n	12	8
	y	36 9	40 9
	sy	3 2	5 4
	P	—	<0 05
Trabecular bone area of periosteal callus (%)	n	5	5
	y	23 67	16 64
	sy	12 99	8 04
	P	—	>0 05

DISCUSSION

The present experiments indicated that large doses of 1 α -OH-D₃, i.e. 25 μ g, produced a significant hypercalcaemia and additionally decreased the body weight of the rats by about 20 per cent. This dose and still larger doses probably produce toxic effects in the adult rat. Dose levels of 1 25 μ g did not significantly affect the body weight but the serum calcium level still increased significantly producing slight hypercalcaemia as compared with the controls. Lower dose levels, i.e. 0 125 μ g, did not influence the body weight of the animals and their serum calcium levels rose only slightly, and not

significantly, during treatment. This low dose level probably does not produce any toxic effects in the adult rat.

In addition to these general effects there were also specific alterations in the composition and in the other examined parameters of the fractured tibia and the periosteal callus during treatment with 1 α -OH-D₃. An acceleration of the consolidation rate of the fracture tested manually was recorded in all treatment groups compared with the controls. Furthermore the mineralization of the fractured bone increased as evidenced by the total ash content and by the amount of mineral, expressed as a percentage of the wet weight, when treated with the low dose

Table 3 Parameters of fractured tibia in rats treated over a period of 6 weeks with 1.25 μ g and 0.125 μ g of 1 α -OH-D₃/day, respectively

		Series II		
Fractured tibia		Control rats	Experimental rats (1.25 μ g 1 α -OH-D ₃) (0.125 μ g 1 α -OH-D ₃)	
Wet weight (g)	n	10	10	10
	\bar{y}	1.2839	1.3063	1.3812
	sy	0.1521	0.1188	0.1221
	P	—	>0.05	>0.05
Dry weight (g)	n	10	10	10
	\bar{y}	0.8015	0.8468	0.8831
	sy	0.0783	0.0623	0.0712
	P	—	>0.05	<0.05
Hydrated bone density (w/v)	n	10	10	10
	\bar{y}	1.4120	1.4450	1.4390
	sy	0.0250	0.0320	0.0240
	P	—	<0.05	<0.05
Total ash content (g)	n	10	10	10
	\bar{y}	0.4974	0.5330	0.5570
	sy	0.0444	0.0363	0.0463
	P	—	>0.05	<0.01
Tibia score ^a (%)	n	15	15	15
	\bar{y}	44.18	45.92	46.61
	sy	2.88	1.75	2.86
	P	—	>0.05	<0.05
Trabecular bone area of periosteal callus (%)	n	5	5	5
	\bar{y}	31.50	29.87	32.40
	sy	11.26	14.17	14.74
	P	—	>0.05	>0.05

levels. These observations are partly supported by similar results achieved by Vitamin D₃ treatment in which the uptake of 45 Ca and thus the mineralization rate of the healing of autogenous bone grafts in rabbits was enhanced (Donatelli et al 1962). Furthermore the ash content of the rat callus was observed to increase as a result of Vitamin D₃ treatment (Steier et al 1967).

The effect of 1 α -OH-D₃ was also an increase in wet and dry weights of the fractured bone indicating an increase of organic matrix components. When calculating the amount of water in per cent of wet weight it was noted that there was an increase in water content of the fractured

bone treated with 2.5 μ g doses. In contrast the water percentage diminished in the fractured tibias treated with the other dose levels. The organic material expressed as a percentage of the wet weight increased slightly in the group treated with 2.5 μ g and was mainly unchanged in the other groups. On the other hand the total dry weight increased significantly in the group treated with 0.125 μ g of 1 α -OH-D₃. In a previous study it has been observed histologically that Vitamin D₃ accelerates the organic phase of fracture repair (Udupa & Prasad 1963).

At all dose levels of 1 α -OH-D₃, the capacity to increase the cortical bone thickness in the tibia adjacent to the fracture was demonstra-



Figure 1 Microradiograph of tibial fractures after 6 weeks treatment with 1α -OH-D, A=control B=treatment with $0.125 \mu\text{g}$ dose. The differences are small, but the bone trabeculae are stronger in the treated group compared with the control.

ted. This can probably be seen as an increase in either periosteal or endosteal new bone formation. The hydrated bone density, however, decreased when treated with large doses and increased with the lower dose levels. The trabecular bone area of the periosteal callus did not increase significantly in the different treatment groups, although at the low dose level, i.e. $0.125 \mu\text{g}$, there was a bone increasing effect.

The conclusion drawn from these experiments is that the dose level of $0.125 \mu\text{g}$ of 1α -OH-D₃ can best promote healing of rat fractures. It increases the mineral in fractured bone and enhances the cortical bone mass as well as the periosteal callus without producing hypercalcaemia or significantly affecting the body weight of the animals.

This beneficial effect of low doses of 1α -OH-D₃ may be explained by a direct action on the bone producing cells. There is some evidence that metabolites of Vitamin D₃ may act via physiological protein receptors in bone cells (Kream et al 1977). On the other hand there may be a secondary effect on bone due to the ability of 1α -OH-D₃ to increase the intestinal absorption rate of calcium (Peacock et

al 1974). The increase in the serum calcium level may inactivate the parathyroid glands and thus decrease the activity of the osteoclasts allowing bone forming cells to activate and increase both the mature bone mass and the formation of callus bone.

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CHANGES IN CALCIUM AND HYDROXYPROLINE CONTENT OF CORTICAL BONE AFTER COMPRESSION AND NEUTRAL PLATE FIXATION

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Calcium and hydroxyproline content of intact rabbit tibio-fibular bone was assayed chemically 1 day to 36 weeks after compression and neutral plate fixation with a 4-hole stainless steel ASIF/DCP plate

During the first three postoperative weeks calcium content of the cortical bone decreased by an almost significant amount ($P < 0.05$) thereafter calcium values remained subnormal but did not differ significantly from initial postoperative values. Hydroxyproline content increased steadily throughout the experiment ($P < 0.001$).

The changes in chemical composition of the bone were of the same magnitude after compression and neutral plate fixation. The results suggest that the cancellous transformation of cortical bone known to take place under rigid plates reflects an active remodelling process of the bone in which the calcium and hydroxyproline content changes only slightly.

Key words: bone, bone plates, fracture fixation, calcium, hydroxyproline

Accepted 10 III 78

In the treatment of certain fractures of long bones, compression plate fixation provides considerable stability and enables subsequent closure of the fracture gap by primary fracture healing (Muller et al 1963, Schenk & Willenegger 1964, Olerud & Danckwardt-Lilliestrom 1968). However, while providing conditions conducive to fracture repair, the attachment of rigid plates to cortical bone simultaneously calls forth a structural derangement of the underlying bone. Uthoff & Dubuc (1971) drew attention to the profound cancellous transformation that occurred after plating of osteotomized canine femora, and Gordes et al (1975b) reported similar changes after plate fixation of osteotomized rabbit tibio-fibular bones. Recent reports suggest that the cancellous

transformation of plated cortical bone is accompanied by a decrease in the mineral content of the bone. Gordes et al (1975a) reported that 24 weeks after rigid plate fixation of rabbit tibio-fibular bones the mineral content, as measured with a gamma ray attenuation technique, had decreased 26 per cent. Using a similar technique Stromberg & Dalén (1976) and Tonino et al (1976) also found that the mineral content of intact canine femora had decreased after rigid plating.

Contrasting with these observations are those of Schenk & Willenegger (1964) who showed, with a fluorescence labelling technique, that the renewal rate in osteotomized cortical bone increases during primary bone healing. Coutts et al (1973), by measuring

the rate of bone formation in canine dog tibia with tetracycline labelling, also observed a reduced stimulus to new bone formation in tibia bone subjected to compression loading.

No figures are available for the chemically-determined content of calcium and collagen in tibia bone subjected to rigid plate fixation. The aim of this study was to compare, in rabbit tibio-fibular bone, the effects of compression versus neutral plate fixation on the chemically determined content of calcium and hydroxyproline.

MATERIAL AND METHODS

Surgical procedure

Twenty adult rabbits weighing from 2 400 to 3 850 g were used. Both tibio-fibular bones were exposed through a straight incision and a stainless steel uniaxial dynamic compression plate (ASIF/DCP) was firmly attached to the anterolateral face of the left tibia with a specially devised plate holder. The plate which was less than half as long as the tibia was positioned so that its midpoint lay directly over the tibio-fibular junction. On the right tibia compression was applied between the most proximal and the most distal screws, with the two middle screws being driven home in a neutral fashion. The entire tubular segment between the two outermost screws was thus subjected to compression. On the left tibia the uniaxial plate was attached without compression. Postoperatively, the animals were housed in separate cages in which they were allowed to move about freely. Seven animals were excluded from the study because of infection (1) or a fracture under the plate (6). Fractures of the plated bones occurred bilaterally in four, in the right tibio-fibular bone in one and in the left in one.

A designated number of animals were killed at 1 and 3 days, and 1, 3, 6, 12, 18, 24 and 36 weeks after the operation. Tubular sections from the midshaft of the tibio-fibular bone under the plate were taken for chemical analysis.

Chemical analysis

The samples were carefully freed of soft tissue with the periosteum being preserved intact. The bone samples were defatted in several changes of acetone and air-dried to a constant weight and then hydrolysed in 6 N hydrochloric acid at 130°C for 3 hours. One portion of the hydrolysate was

neutralized with NaOH and used to determine hydroxyproline content. The method described by Pikkariainen (1968) without benzene extraction was used. The coefficient of variation of the method was ± 2.7 per cent. The remainder of the hydrolysate appropriately diluted was used to determine calcium content with a Unicam SP 90 atomic absorption spectrophotometer (Unicam Instruments Ltd, Cambridge, England). Calcium was measured in 1 per cent lanthanum chloride.

Sixty-two samples from 31 animals were analysed successfully, the samples from two animals were excluded because of technical failure. The 31 animals were divided into five groups based on when, postoperatively, they were killed: 1-3 days postoperatively (6 animals), 1-3 weeks (12 animals), 6-12 weeks (5 animals), 18-24 weeks (5 animals) and 36 weeks (3 animals).

Statistical methods

To test the statistical significance of the differences between the compression plated and neutrally plated bones the paired *t* test was used. *t* statistics for two means were used to compare the significance of differences among several groups. $P > 0.05$ was taken to be not significant.

RESULTS

Table 1 shows the mean calcium and hydroxyproline content for the five groups of animals. Figure 1 adds to this the corresponding calcium/hydroxyproline ratios. During the first three postoperative weeks, the calcium content of both the compression and neutrally plated bones declined by an almost significant ($P < 0.05$) 10 per cent. Thereafter, calcium values remained subnormal in both groups of bones, but the initial postoperative value and that at 36 weeks did not differ significantly. In all bones, hydroxyproline content increased steadily, the difference between the initial postoperative value and that at 36 weeks being highly significant ($P < 0.001$). Consequently, the ratio of calcium to hydroxyproline gradually declined, until at 36 weeks the decrease in this ratio for both groups of bones was almost significant ($P < 0.05$). At none of the five periods was there any significant difference either in calcium or hydroxy-

proline content or in the calcium/hydroxyproline ratios between the bones plated with compression and those plated with neutral fixation.

DISCUSSION

The attachment of a rigid metallic plate to the cortical bone can induce untoward changes in the underlying bone. G6rdes et al. (1975b) observed that during the first

24 weeks after neutral rigid plate fixation of rabbit tibio-fibular bone cancellous transformation was progressive and profound. In our laboratory, the rigid plate fixation of intact rabbit tibio-fibular bone induced similar changes. Thirty-six weeks after compression plate fixation the frequency of cavities in cross sections of the tubular bone underneath the plate had increased 3-fold in neutrally plated bone cancellous transformation was of the same magnitude (Slatis et al. 1978).

Table 1 Concentration of calcium and hydroxyproline (mg/g dry weight of bone) in the tibio-fibular bones of 31 rabbits after compression and neutral plate fixation. Mean \pm s.d.

Time after plate fixation	No of animals	Calcium		Hydroxyproline	
		Compression	Neutral	Compression	Neutral
1-3 days	6	189.8 \pm 20.6	193.5 \pm 21.0	21.8 \pm 1.1	22.1 \pm 0.9
1-3 weeks	12	174.3 \pm 12.0	171.6 \pm 31.6	22.9 \pm 0.7	23.0 \pm 0.9
6-12 weeks	5	179.3 \pm 19.0	183.1 \pm 17.6	23.3 \pm 0.8	23.4 \pm 0.6
18-24 weeks	5	187.3 \pm 16.5	176.2 \pm 12.4	24.2 \pm 1.6	24.3 \pm 1.7
36 weeks	3	176.8 \pm 26.4	182.2 \pm 6.50	25.4 \pm 2.5	24.7 \pm 1.8

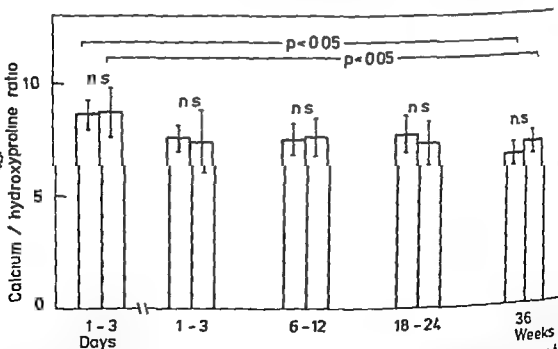


Figure 1 Calcium/hydroxyproline ratio in intact rabbit tibio-fibular bone after rigid plate fixation with compression plates (shaded columns) and with neutral plates (white columns). Closed bars represent one standard deviation.

Coutts et al (1973) reported no differences in porosity or in new-bone formation between bones plated with and without compression but otherwise plated identically. These authors attributed the observed changes not to compression but to the rigidity of the plate. Recently, the use of plates with various stiffness properties has shown that plates with bending properties closely resembling those of the underlying bone bring about less porotic changes in subular bone than do rigid plates (Tomino et al 1976).

During the first 3 weeks of this study the calcium content of all plated bone decreased and thereafter remained subnormal. The mineral loss was less profound than that reported by Gordes et al (1975b). This may be because mineral loss is greater in the plated osteotomized bone than in the intact bone. Moreover, the method of assaying calcium content may also have a bearing on the estimate arrived at. Results achieved with the gamma-ray attenuation technique are apt to be influenced by changes in bone density. When cancellous transformation is accompanied by an increase in the amount of soft tissue elements in the cortical cavities, estimates of mineral content tend to be low (Meunier et al 1970, Karjalainen 1973). Hence, the continuous decline in mineral content reported by Gordes et al (1975a) may not only reflect a decrease in the amount of mineral in the plated bone, but also the cancellous transformation of the cortical wall adjacent to the implant. The steady increase we observed in the amount of hydroxyproline, together with the corresponding decrease in the calcium-hydroxyproline ratio, is evidence of an active turnover of collagen - the prerequisite for the remodeling of bone tissue and for the formation of mature new bone subperiosteally.

According to Perren et al (1969), after plating, the compressive forces gradually diminish even in intact bone. This would mean that at the end of 36 weeks only slight compressive forces were still acting on the cortical bone. Our observation that changes

in the bones plated with and without compression were similar supports the view that the adverse changes in the plated bone are attributable not to the compression *per se*, but to the effect of the rigid plates.

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STUDIES ON MECHANICAL STRENGTH OF BONE

Torsional Strength of Normal Rabbit Tibio-Fibular Bone

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A method is described at low velocities, the effect of the torsional properties are analysed

Rabbit tibio-fibular bones exhibited right to-left differences in energy absorption capacity (up to 100 per cent) torsional rigidity (71 per cent) torque moment at fracture (63 per cent) and angular deformation (57 per cent). The scatter in energy absorption was more dependent on differences in angular deformation (strain) than on differences in torque moment (stress). No statistically significant dominance of either side could be observed.

The biomechanical properties of the bones were dependent on the body weight of the test animal and the transverse dimensions of the bone but were not influenced by the small variations measured in the chemical composition of normal bone.

Key words: bone, bone strength, chemical composition of bone, experimental measurement of bone strength.

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Bone is a heterogeneous and anisotropic material, its mechanical properties have been investigated extensively. For this purpose the bone is usually subjected to pure tensile or compressive forces or a combination of these two as in bending or torsion.

Measurement of the torque capacity of tubular bone is a suitable method for investigation of mechanical properties because a torsional load exerts simultaneously tensile, compressive and shear forces each acting in a different plane on the same region of the bone. Torque moment is constant in every section of the specimen tested and the result is not critically dependent on the position of the supports of the specimen, as in the

bending test (Brooks et al 1970, Burstein & Frankel 1971).

On the other hand tests on the strength of osseous tissue have revealed a number of features which have to be considered in analysing the results. The results obtained are critically dependent on the rate of loading (McElhanev 1966, Burstein & Frankel 1968, Panjabi et al 1973), the shape and structure of the test specimen (Dempster & Coleman 1961), the stage of mineralization of the bone (Vose 1962, Currey 1969), the relation between the fibre orientation and the forces acting (Ascenzi & Bonucci 1967, 1968, Vincentelli & Evans 1971) and the effects of the storage and post mortem changes (Sedlin

■ Hirsch 1966, Stromberg & Dalen 1976a)

However precise the mechanical equipment used for measurements, biological variations inevitably affect the results. Within a single species, differences in mechanical properties have been reported between the right and left paired bones (Puhl et al 1972, White et al 1974, Stromberg & Dalen 1976b).

During the course of studies on the healing of experimental fractures (Paavola et al, to be published) the need became evident for a reliable method with which to follow the increase in mechanical strength in healing bone. To ensure that the method devised gives valid results the present study was undertaken to investigate the precision and linearity of the torsional testing method and the biological variations which may influence the test results.

MATERIALS AND METHODS

Experimental animals

Fifteen healthy rabbits of various ages and of both sexes weighing from 2400 to 4850 g (mean 3275 ± 682 g s.d.) were selected for the investigation.

After the animals had been killed with an overdose of sodium pentobarbitone the tibio-fibular bones were exarticulated and dissected out, with the periosteum intact. Between the various test procedures the bones were kept moist in 0.9 per cent NaCl solution at room temperature.

Each left and right bone was loaded until failure with external torsion along the longitudinal axis of the specimen.

Measuring equipment

A special apparatus for torsionometry was constructed in collaboration with the Technical Research Centre of Finland (Figure 1).

The proximal end of the bone specimen was held rigidly while the distal end was connected with the rotating head of the torsionmeter. The torque moment was transmitted to the test specimen at an angular velocity of 3.6 degrees/second. Progressive deformation of the specimen was produced by turning the rotating head with a number of turns on the driver. The deformation was registered with a linear potentiometer. Two strain gauges connected to a Wheatstone bridge measured the magnitude of the torsional moment. The output from the Wheatstone bridge moved directly on the distal end of the torsion shaft was displayed on a Peckle analyser (Peckle Universal Amplifier, type 591 DNH, Holland). The output from the analyser (magnitude of torsional moment) was further displayed on the vertical axis and the output from the potentiometer (angular deformation) on the horizontal axis of a paper recorder (Hewlett Packard, type 7015 A). As the angular velocity was constant during each experiment, the torque moment was determined as a function of the angular deformation of the specimen (Figure 4).

Calibration of the torsionmeter

The linearity of the measurements obtained with the equipment was evaluated with a calibration torque wrench connected to the torsionmeter exerting different known torques on the measure-

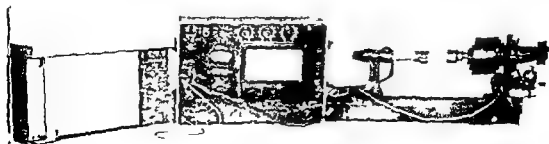


Figure 1 The torsional apparatus with the torsion device, Peckle micro-strain analyser and paper recorder

ence There was a linear relation between the magnitude of the torque applied and the output signal of the analyser (Figure 2). Comparable results were obtained with left- and right-handed rotation on the turning head. Figure 2 depicts the relation between the various forces applied with the calibration torque wrench (kpm) and the percentage deviation of the corresponding output signals obtained. The data indicate that the proportional error increases exponentially as the force on the test specimen is

of the force on the test specimen is At maximal loading of the test equipment (24 kpm) the proportional precision of the test was 1.0–1.5 per cent. In the animal experiments, the torque applied to the bones ranged from 0.15 to 0.20 kpm. The measuring error of the torsionmeter in this range of load was less than per cent.

Biomechanical testing of the bones

Before the test procedure the fibula was sawn through at the tibio-fibular junction leaving a stump of bone of 1.2 mm. Each end of the specimen was embedded in a nut with epoxy resin (Araldite Express, Henkell, Germany) which has a curing hardening time of 20 minutes. The length of the shaft between the nuts was 8.5 centimeters in 1 specimen. The resin retained a constant shape during solidification. While the resin solidified the bones were laid against an L-shaped

metal support, so that the nuts were held perpendicular to the specimen.

Connection between the bone specimen and the torsional equipment was achieved by inserting the nuts into two tightly fitting holders (Bahco 30 mm ϕ) firmly connected to the torsionmeter (Figure 3). No motion could be observed between the test specimen and the equipment.

This rapid fixation procedure (30 minutes for a single specimen) made it possible to analyse the torque resistance of fresh bone without any storage procedure before testing. Close up photographs were taken of all the fractured specimens for later analysis of the fracture line (Figure 3).

Biomechanical calculations

A typical load-deformation curve of a tibial bone is shown in Figure 4.

Maximum torque moment (M_t) was determined from the maximum deflection of the curve (to the nearest 0.1 mm) and expressed in Nm.

Maximum angle deformation (θ) was measured directly from the horizontal axis of the curve and expressed in degrees.

Energy absorbed until ultimate failure (W_t) of the bone was calculated from the area under the curve, which was measured with a planimeter (type HAFF 317) ($W_t = \int_0^{\theta} M_t d\theta$). The values were expressed in Nm (Burstein & Frankel 1971).

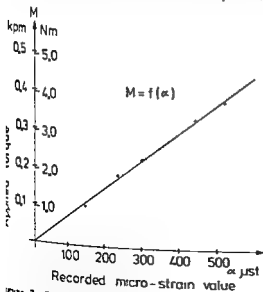


Figure 2 On the left linear relation between force applied and results obtained Ordinate known torque applied, Abscissa micro-strain value recorded

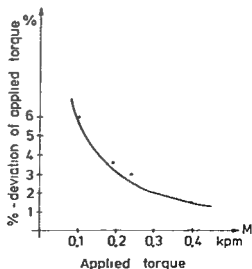


Figure 2 On the right the percentage deviation of the readings from the torque applied at various lengths

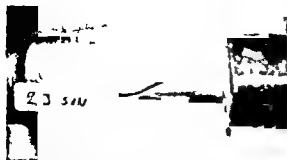


Figure 3 A typical spiral fracture after torsional loading of normal rabbit tibio-fibular bone. The crack cuts through the tibio-fibular junction at 45 degrees to the longitudinal axis of the specimen

Torsional rigidity (G) of the specimen was measured from the slope of the linear portion of the curve and expressed in Nm/degree ($G = dM_t/d\theta_t$) (White et al 1974, Panyabi et al 1973).

The difference between results obtained for the right and left paired bones was expressed as

$$\left[\frac{(\lambda) \text{ right} - (\lambda) \text{ left}}{(\lambda) \text{ right} + (\lambda) \text{ left} / 0.5} \right] 100 = \% \text{ difference}$$

The data were processed with a computer and standard statistical methods were employed to test the significance of the results. $P > 0.05$ was taken as non significant. The possibility that one measured variable influenced any other was examined by correlation analysis and the coefficient of correlation (r) calculated. The percentage error of the differences between the paired bones was calculated from duplicate determinations (standard error of the means, SEM) using the formula $SEM = \sqrt{d^2/2n}$, where d is the difference between duplicate measurements and n the number of pairs of bones measured.

Measurement of bone dimensions

At sacrifice both tibio-fibular bones were radiographed on contact film. The entire length of the bone was measured directly from these radiographs.

After the torque test procedure a standardized transverse section was sawn from the tubular bone at the level of the tibio-fibular junction. Contact microradiographs of these specimens were made on high resolution X-ray film. The area of cross section and medullary cavity was planimetered from tenfold enlargements of these radiographs. The values so obtained were reduced mathematically to the actual size of the bone. The outer and inner diameters of the tube were determined with the same techniques.

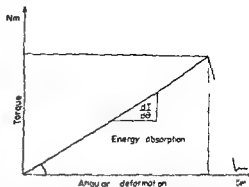


Figure 4 Load deformation curve where torque moment is determined as a function of angular deformation. Energy absorption equals the area under the curve and torsional rigidity is determined from the slope of the linear portion of the curve.

Chemical analysis

Each fresh tubular section was weighed and stored in airtight containers and deep-frozen for chemical analysis.

The contents of calcium, phosphorus, hydroxyproline, hexosamines and total nitrogen were determined at the Department of Medical Chemistry, University of Turku with the techniques previously described by Penttinen (1972).

RESULTS

The fractures produced were remarkably uniform in type. In all specimens there was a spiral fracture at 45 degrees to the longitudinal axis of the bone, with an additional spiral crack running up and down the bone beyond the actual limits of the fracture (Figure 3). The fracture appeared at the level of the tibio-fibular junction. In paired bones the two fractures seemed to be identical in appearance. The load-deformation curves, although very similar in shape varied greatly in termination point. The mechanical properties of the bones in relation to the weights of the animals are presented in Table I.

Correlation between body weight, bone dimensions and mechanical properties of bone

There was a highly significant correlation ($P < 0.001$) between body weight and the

Table 1 *Torsionometric characteristics of rabbit tibio-fibular bones (with an angular velocity of 3.6 degrees/second)*

No	Animal Body weight (g)	Maximum torque moment (Nm)		Maximum angular deformation (degrees)		Energy absorption at fracture (Nm)		Torsional rigidity (Nm/degrees)	
		Right	Left	Right	Left	Right	Left	Right	Left
1	(2400)	0.68	0.81	3.60	3.51	0.03	0.03	0.19	0.23
2	(2610)	1.07	0.96	5.18	4.43	0.06	0.04	0.19	0.21
3	(2660)	1.33	1.38	6.37	6.94	0.09	0.10	0.19	0.20
4	(2730)	1.07	1.01	6.15	5.18	0.07	0.05	0.16	0.19
5	(2750)	1.38	1.12	7.11	7.07	0.10	0.09	0.20	0.19
6	(3003)	1.38	1.45	7.38	7.07	0.11	0.09	0.20	0.21
7	(3050)	1.08	0.96	5.14	5.00	0.06	0.05	0.21	0.19
8	(3100)	1.12	1.10	6.10	5.84	0.07	0.07	0.17	0.18
9	(3200)	1.30	1.23	7.46	6.59	0.10	0.08	0.16	0.18
10	(3250)	1.37	1.36	4.48	4.79	0.06	0.07	0.33	0.28
11	(3530)	1.22	1.26	5.71	5.88	0.07	0.08	0.22	0.22
12	(3800)	1.40	1.34	5.36	5.36	0.08	0.07	0.26	0.25
13	(4050)	1.21	1.36	4.08	4.14	0.05	0.06	0.30	0.30
14	(4150)	1.84	1.86	7.16	6.50	0.14	0.12	0.28	0.31
15	(4850)	1.90	1.89	6.19	6.01	0.12	0.12	0.33	0.31
Mean (s.d.)		1.29 (0.30)	1.27 (0.31)	5.83 (1.20)	5.60 (1.13)	0.08 (0.03)	0.07 (0.03)	0.23 (0.06)	0.23 (0.05)

Table 2 *Correlations of the body weight of the animals and bone dimensions with the biomechanical properties of rabbit tibio-fibular. Correlation coefficients and significance levels are presented and, if negative, marked—*

	Maximum torque moment	Maximum angular deformation	Energy absorption at fracture	Torsional rigidity
Body weight	0.794 (+++)	0.092 (\ S)	0.552 (++)	0.773 (+++)
Entire cross-sectional area	0.400 (+)	-0.240 (N S)	0.098 (\ S)	0.647 (+++)
Area of cortical bone	0.351 (N S)	-0.320 (N S)	0.037 (\ S)	0.679 (+++)
Bone length	0.500 (++)	0.381 (+)	0.482 (++)	0.341 (\ S)
Outer diameter of tubular bone	0.185 (N S)	0.272 (N S)	0.043 (\ S)	0.480 (++)
Inner diameter of tubular bone	0.327 (N S)	0.045 (\ S)	0.171 (\ S)	0.389 (+)

N S = not significant
 (+) = $P < 0.05$
 (++) = $P < 0.01$
 (+++) = $P < 0.001$

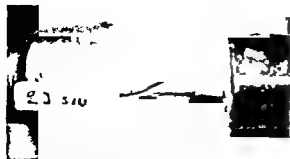


Figure 3 A typical spiral fracture after torsional loading of normal rabbit tibio-fibular bone. The crack cuts through the tibio-fibular junction at 45 degrees to the longitudinal axis of the specimen.

Torsional rigidity (G) of the specimen was measured from the slope of the linear portion of the curve and expressed in Nm/degree ($G = dM_t/d\theta_t$) (White et al 1974, Panjabi et al 1973).

The difference between results obtained for the right and left paired bones was expressed as

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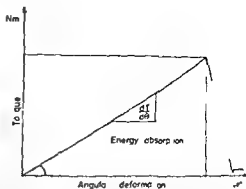


Figure 4 Load deformation curve where torque moment is determined as a function of angular deformation. Energy absorption equals the area under the curve and torsional rigidity was determined from the slope of the linear portion of the curve.

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Correlation between body weight, bone dimensions and mechanical properties of bone

There was a highly significant ($P < 0.001$) between body weight and

Table 4 Chemical composition of rabbit tibia-fibulae. Data of right and left paired bones expressed as mg/g dry weight of bone

	Calcium (s.d.)	Phosphorus (s.d.)	Hydroxyproline (s.d.)	Hexosamines (s.d.)	Nitrogen (s.d.)
ht	256.5 (15.9)	119.6 (4.5)	28.7 (1.1)	2.04 (0.28)	34.7 (1.5)
l	248.5 (22.3)	118.1 (3.1)	28.2 (1.2)	2.19 (0.39)	36.9 (5.5)
test for paired bones	NS	NS	NS	NS	NS

Correlation analysis revealed no significant relations between the mechanical properties and chemical composition of the bones.

Paired bone specimens exhibited varying mechanical properties. According to many investigators, however, right-left differences in bones from different animals and human

DISCUSSION

Bone is a composite material exhibiting elastic, viscoelastic and plastic properties (Feldman 1965, Burstein et al 1975). It can resist tensile forces as compared to compressive forces in a ratio of about 3:4 (Currey 1970). Consequently the great majority of cortical bone fractures are caused by tensile forces, regardless of whether the force responsible is tension, bending or torsion. The ultimate tensile strength of bone is less than the ultimate shear strength. Therefore in torsion, shear forces result in tensile and compressive forces acting at angles of 45 degrees to the plane of shear (Figure 5), and a spiral fracture occurs at 45 degrees to the axis of the bone.

Bone can absorb noticeably more energy when force is applied at high velocity (Sammarco et al 1971, Panjabi et al 1973). Hence bone behaves as a tough material at slow strain rates and as a brittle material at high strain rates. The microscopical appearance of the fracture line has been reported to be different in low- and high-velocity fractures (Pickarski 1970). Halving and doubling of low velocities, as in the present study, does not significantly change the maximum torque capacity (Stromberg & Dalen 1976b).

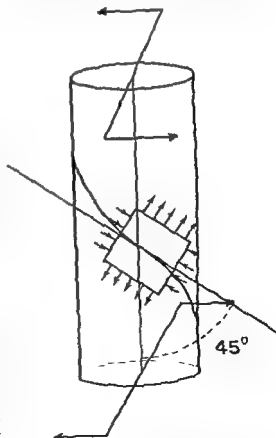


Figure 5 Shear forces arising from torsion, resulting in tensile and compressive forces at 45 degrees to the plane of shear. A spiral fracture will occur at 45 degrees to the axis of the bone.

cadavers have no statistical significance (Currey 1969, Puhl et al 1972, White et al 1974, Stromberg & Dalen 1976b). This was confirmed in the present study. However, the right-left variation in mechanical properties of paired bones must be known in any biomechanical investigation in which the contralateral bones are to be used as controls. Stromberg & Dalen (1976b) reported the variation for torque capacity in canine femora to be 3.1 per cent, compared with 6.3 per cent in this report. The difference may be due to the different species used and to the almost ten-fold greater torsional moment used in their investigation.

The results suggest great variation in the amount of energy absorbed until fracture. This agrees with the observations reported by Bechtol (1959) in bending tests and Puhl et al (1972) in torsional testing. The present results show that bone can sustain very little angular deformation without fracturing. Accordingly, changes in angular deformation lead to considerable variation in the energy absorption capacity of bone.

A high correlation was established between body weight and the dimensions of the tubular bone. The biomechanical variables measured, with the exception of angular deformation, were highly dependent on body weight, which corroborates the observations made by Lindsay & Howes (1931). Thus in a series of experimental animals of different weights torsional properties of whole bone specimens should be corrected for the weights of the animals, in order to arrive at comparable results.

As was expected, these normal animals showed little variation in the chemical composition of the bone, and no significant differences were observed between paired bones. In normal bone specimens the dimensions of the bone are more important for the maintenance of torsional strength than are the changes in the chemical content of the bone. With the known error of the test equipment and the biological variations of paired bones, this torsionometric assessment of

bone strength is a suitable method for analysis of biomechanical bone characteristics.

ACKNOWLEDGEMENT

I would like to thank Assistant Professor Risto Penttinen, M.D., of the Department of Medical Chemistry (Head Professor Eino Kulonen, M.D.), University of Turku, Finland, for his help in the preparation of this paper.

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STUDIES ON MECHANICAL STRENGTH OF BONE

II *Torsional Strength of Cortical Bone after Rigid Plate Fixation with and without Compression*

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Biomechanical properties of intact rabbit tibio-fibulae were investigated with torsional loading 1 day to 36 weeks after fixation using 4-hole stainless steel ASIF/DCP plates with and without compression.

During the first 12 weeks energy absorption and torque moment increased slightly as a result of subperiosteal new bone formation following application of the plates. There was a concomitant increase in the yield properties of the bone reflecting progressive porotic transformation. Thereafter up to 36 weeks postoperatively the values for energy absorption, torque moment and angular deformation gradually declined in both groups of bones. The differences between normal control bones and plate bones at 36 weeks were 70.1, 53.0 and 26.3 per cent respectively. The decay of torsional strength was the same whether or not compression was used in the plate fixation.

The results suggest that even in normal bone rigid plates induce a considerable loss of strength due to the cancellous transformation that is known to cause in cortical bone.

Key words: bone, bone plates, fracture fixation, experimental measurement of bone strength.

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Rigid plate fixation of fractured bones initially provides conditions conducive to primary bone healing, but protection of the bone from normal loading stress may induce atrophic changes and a decrease in the mechanical strength of the bone during the later stages of repair. Refractures have been reported after removal of the plates (Richon et al 1967, Dietsch & Zenker 1973, Solheim 1974).

Both adverse effects on bone tissue as a structure (Schenk & Willenegger 1967, Uhthoff & Dubuc 1971, Gordes et al 1975a, 1976) and reduction of the bone mineral mass

(Gordes et al 1975b, Stromberg & De 1976) have been reported in cortical bone after immobilization with a rigid plate. The magnitude of the bone changes seems to depend on the stiffness of the plate and structural alterations have been less after the use of plates with mechanical properties resembling those of bone (Åkeson et al 1975, Tonino et al 1976, Woo et al 1976). The axial compression applied to the bone and conveyed to the underlying bone does appear to alter the mechanism of repair (Lettin 1965, Perren et al 1969). Not scant attention has been paid to the effect

effect on the mechanical properties of bone. The object of this study was to measure changes in torsional strength at different intervals after application of rigid plates to normal rabbit tibio-fibular bones, and to assess the effect of additional axial plate compression on the changes observed.

MATERIAL AND METHODS

Test procedure

Tests were applied to the tibio-fibulae of 40 adult rabbits weighing from 2400 to 3850 g. The bones were exposed through a straight lateral incision and a commercial stainless steel four hole dynamic compression plate (ASIF/DCP) was attached only to the anterolateral face of the tibia. The tibio-fibular junction served as a landmark for the exact positioning of the midpoint of the plate. On the right tibia, compression was applied between the most proximal and the most distal screw and the two middle screws were tightened in a neutral position. The entire tubular segment between the two outermost screws was thus subjected to compression. On the left tibia, a similar four hole plate was attached to the bone without compression.

Postoperatively the animals were housed in separate cages in which they could move freely. Seven animals were excluded from the analysis because of infection (1) or subsequent fracture under the plate (6). In one animal a fracture occurred in the right leg, in one animal in the left and in four animals in both legs.

Testing of the mechanical properties

The animals were killed 1 and 3 days, and 1, 3, 12, 18, 24 and 36 weeks after the operation. The tibio-fibular bones were excised and freed from any soft tissue but the periosteum and any callus tissue were preserved intact.

Prior to the test procedure the bones were radiographed before and after removal of the plates. Examination of the radiographs excluded three more animals from the analysis because of faulty positioning of the plate or fractures at the level of the screw holes. In order to eliminate the stabilizing effect of the fibula, this was severed distally at the tibio-fibular junction leaving a proximal remnant of 12 mm. The specimens were kept in physiological saline at room temperature before the test.

As previously described (Paavola 1978) the



Figure 1A Rabbit tibio-fibular bone 36 weeks after application of a rigid steel plate. Note the formation of new subperiosteal bone round the plate.



Figure 1B A typical spiral crack passing through a screw hole at the tibio-fibular junction (arrow) after torsional loading of the bone specimen 36 weeks postoperatively. Note the porous cavity of the cortical bone under the plate.

ends of the bones were embedded in nuts with epoxy resin leaving a constant length (8.5 cm) of bone for testing. The specimen was then fitted into the sockets of the torsionmeter and subjected to external rotation at a constant deformation speed of 3.6 degrees/second.

Calculations

From the load-deformation curve obtained which represents the torque moment as a function of the angular deformation of each specimen the following biomechanical properties were measured:

As reported earlier (Paavola 1978) the mechanical properties of the rabbit tibio-fibular bone apart from angular deformation are

critically dependent on the body weight of the animal. Hence the data obtained for each bone specimen were corrected for the weight of the animal. Using linear regression curves for body weight in relation to torque moment, energy absorption and torsional rigidity in the control series, the biasing effect of body weight was reduced by multiplying the test values obtained by a constant which standardized them for the mean body weight (3275 g) of the control group.

Mechanical properties of 57 specimens were analysed successfully; three specimens had to be discarded because of technical failure. The 57 specimens were divided into five groups according to when the animals were killed: 13 days (4+4 specimens), 13 weeks (9+9 specimens), 6-12 weeks (7+8 specimens), 18-24 weeks (5+5 specimens) and 36 weeks postoperatively (3+3 specimens). The means and their standard deviations were calculated for each of these. Statistical analysis of the influence of compression was made in paired bones and of the influence of time after plating in the different groups. The statistical significance of the differences between the paired bones was assessed with a paired *t* test. Between the various groups statistical analysis for two means was made. $P > 0.05$ was taken to be non significant.

Sources of error

The experimental error for biomechanical differences between paired bones of the same animal, expressed as SEM values for the percentage deviations of the paired variables measured from the mean value was as follows: torque moment at fracture 63 per cent, deformation at fracture 57 per cent, energy absorbed at fracture 100 per cent, torsional rigidity 71 per cent. There was no statistically significant right-to-left dominance between the pairs of bones (Paavolainen 1978).

RESULTS

The biomechanical properties of the bones plated with and without compression in the various age groups are shown in Figure 2. During the first three postoperative days, the torque moment of both the compression and neutrally plated bones fell by almost one standard deviation compared with the values for normal bones reflecting the weakening effect of the screw holes in the tubular bone. At 6-12 weeks postoperatively, the torque

moment had increased almost significantly ($P < 0.05$) in the plated bones whether the plates were applied with or without compression. Thereafter however the torque moment declined continuously up to the 36th week postoperatively. In both types of plating the differences between the initial postoperative values and those obtained at 36 weeks were statistically significant ($P < 0.01$).

Energy absorption, i.e. the magnitude of the work needed to deform the bone up to the point of failure, increased steadily for 6-12 weeks postoperatively. At this stage the values approached the values of energy absorption measured in normal bones. Thereafter however the values of energy absorption in both groups of bones gradually declined. The difference between the initial postoperative values and those at 36 weeks was highly significant ($P < 0.001$) whether or not compression had been used at plating.

The changes in angular deformation were closely related to the changes in energy absorption. The values for deformation seemed to reach a peak at 6-12 weeks postoperatively. Thereafter they declined slightly. The differences between the initial postoperative values and the values at 36 weeks postoperatively were almost statistically significant ($P < 0.05$).

Only slight changes were observed in the values for the torsional rigidity of the bone. At 6-12 weeks postoperatively the increase in both energy absorption and angular deformation led to diminishing values of torsional rigidity. This means that the slope of the load-deformation curve decreased although at the same time the maximum torque moment increased, both of which factors led to increased values for energy absorption. At 36 weeks, the values for torsional rigidity seemed to approach the initial postoperative values. The differences between the values immediately after the operation and at 36 weeks were statistically significant.

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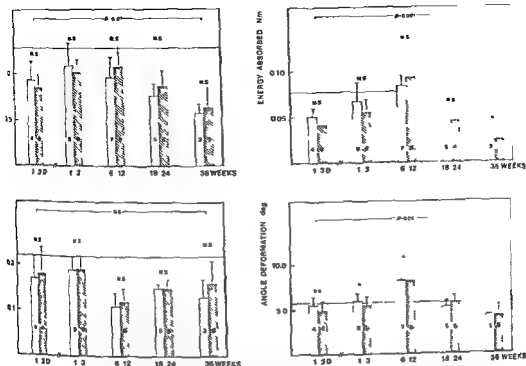


Figure 2A-D Biomechanical properties of intact rabbit tibio-fibular bones after exposure to rigid plates (white columns) and without (shaded columns) compression. Vertical bars represent one standard deviation. The figures in the columns denote numbers of specimens. Statistical significance between groups is indicated by p-values.

DISCUSSION

Application of rigid steel plates to normal rabbit tibio-fibular bones leads to progressive changes in the affected bone. The alterations are characterized by cancellous transformation of the cortex accompanied by increases in the diameters of the tubular bone and medullary cavity (Paavolainen et al. 1978). The cancellous transformation of the bone is of the same magnitude after compression and after neutral plate fixation (Slatis et al. 1978). Morphologically, the porotic cavitation of the cortex closely resembles the changes observed during primary fracture healing (Schenk & Willenegger 1967, Olerud & Danckwardt-Lindstrom 1968, Uthoff & Dubuc 1971, Gordes et al. 1975a).

The present study reveals that plating causes considerable changes in the biomechanical properties of rabbit tibio-fibular bones. For a few days postoperatively the screw-holes in the tubular bone caused a reduction in torque moment and energy absorption values (cf Burstein et al. 1972). After this, the alterations seemed to occur in two phases. In the first phase, 1 to 12 weeks after application of the rigid plate both the torque moment and the energy absorption values increased to almost normal values reflecting increasing strength of the bone as a structure. Simultaneously, however, there was an increase in angular deformation and

bone was obviously due to formation of new subperiosteal bone round the tubular bone (Paavolainen et al 1978)

The concomitant increase in the yielding properties of bone reflects the increasing cavitation of the cortex as a result of cancellous transformation (Slatis et al 1978)

In the second phase III to 36 weeks postoperatively, energy absorption and torque moment values decreased considerably. Meanwhile the angular deformation decreased but torsional rigidity increased slightly. This indicates that in the late stages of adaptation to the plate the bone as a structure loses both strength and flexibility. The alterations during the second phase seem to coincide with progressive porotic cavitation of the cortex, which at 36 weeks amounts to over 40 per cent of the cortical bone (Slatis et al 1978). There were no significant differences between plate fixation with and without compression regarding the decline of biomechanical properties of the underlying bone. Hence it seems that the changes observed are due to the rigidity of the plates and not to the compression *per se*.

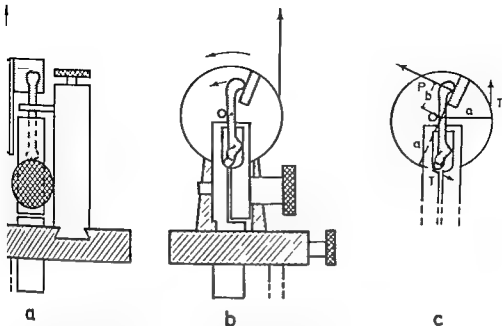
Stromberg & Dalen (1976) plated intact canine femora with commercially available rigid steel plates and compared the test specimens with control bones perforated with the same number of screw holes. Seven months later they found a reduction of 18.3 per cent in torsional capacity and of 22.2 per cent in angular deformation. Our results showed reductions of 53.0 per cent in torque moment and 26.3 per cent in angular deformation of the test specimens when compared at 36 weeks postoperatively with normal intact rabbit tibio-fibulae. The data obtained indicate considerable loss of strength even in normal bones subjected to plating

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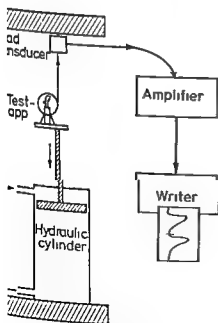
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The bending apparatus — frontal (a) and lateral (b) view. Figure 1c shows that the moment $d(T \times a)$ equals the moment needed to bend the distal part ventrally relative to the proximal (b) (Rø et al 1976)



2 Equipment for measuring mechanical properties of the rat femur

The force T is applied by a hydraulic tensile testing machine type 7-1/1 (AB Lorentzen & Wettres Maskinaffär, Stockholm, Sweden) (Figure 2). The tension in the wire is measured with a load transducer (HBM Kraftaufnehmer Type U1, load range 0–10 kp, Hottlinger Baldwin Messtechnik, Darmstadt, W. Germany) which is connected via an amplifier (HBM Messverstärker KWS/T-5) to a chart recorder (Riken Denshi Co Ltd, Model SP-J5B, Tokyo, Japan). The force is applied with a constant deformation rate, 0.04 radians per second (2.5 degrees per second).

A typical bending stress-strain curve of the intact femur diaphysis is shown in Figure 3. The curve gives information about the maximum stress, the stiffness of the bone in the linear elastic part of the curve ($\tan \alpha$) and the angle of deformation necessary to produce fracture (fracture angle). The area below the curve expresses the energy which the bone can absorb before fracture.

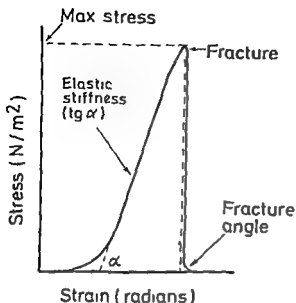


Figure 3 Stress strain curve for bending of the rat femur diaphysis

(2) Epiphyseal plate/metaphysis bending test

The bending moment necessary to produce epiphysiolysis and metaphyseal fracture can also be tested. The bone is placed as shown in Figure 4a with the disc centre and the fulcrum pin just proximal to the epiphyseal plate.

With this arrangement the cam on the test will first give epiphysiolysis followed by displacement of the epiphysis. By continual rotation of the disc the distal part of the metaphysis will fracture. The resulting moment-deformation curve (Figure 4b) has two peak values, the first one represents epiphysiolysis and the second one represents metaphyseal fracture of the bone. As the epiphysial discs of the long bones in rats do not close (Farris & Griffith 1949) this method is not restricted to young rats.

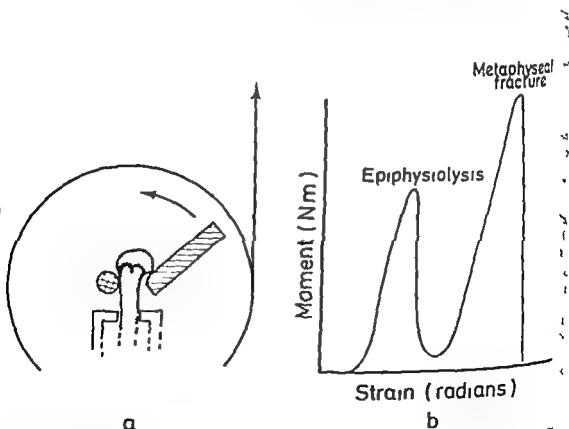


Figure 4 Testing of the epiphyseal plate and the metaphysis in bending (a) Rotation of the disc will first give epiphysiolysis and then metaphyseal fracture. This is recorded as two peak values in the moment deformation curve (b)

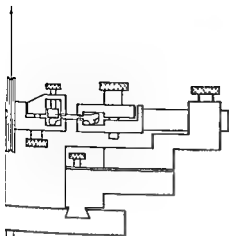


Fig. 5 The arrangement for torsional testing force is applied via a rotating disc as in the testing apparatus

Diaphyseal torsional tests

The torsional testing system is illustrated in Figure 5. The torsional moment is, as in the bending apparatus, applied via a rotating disc. The distal end of the femur is attached to the disc via a special clamp. The clamp which fixes the proximal end of the femur can be moved horizontally and adjusted to different angles when testing fractures united in different positions. The clamps are connected to envelop the ends of the bone (Figure 5). Therefore only part of the rotating moment is transferred to the bone via the clamps, the rest being transferred by the body of the clamps. This arrangement reduces the stress concentration and the chance for fracture at the clamps. The tension of the wire and thereby the bending moment is continually measured as in the bending tests. The stress-strain curve is also principally the same (Figure 3). The bones can be tested by both inward and outward rotation of the distal end relative to the proximal part.

STRESS CALCULATIONS

The stress in the test bone (force/cross-sectional area) depends not only on the

applied moment, but also on the shape and the area of the cross section of the bone. Because of variation in the size and shape of the femurs, not only from one femur to another, but also along the diaphysis in the same bone, the stress calculations can only be approximate.

In earlier investigations these problems have been simplified by calculating the cross-sectional area of the femur as a hollow ellipse (Bell et al 1941). The formula for the maximal bending stress of an elastic isotropic, homogeneous beam with a hollow elliptical cross section, derived from Roark & Young (1975) is

$$\text{Max bending stress } \sigma_m = \frac{M \times b}{I} = \frac{4 \times M \times b}{\pi (ab^3 - (a-t)(b-t)^3)} \quad (1)$$

where M is the maximal bending moment, a and b are the major and minor external radii of the hollow ellipse, t is the thickness of the hollow ellipse and I is the area moment of inertia for an ellipse.

The maximal torsional stress for a hollow ellipse is

$$\tau_m = \frac{T \times b}{I_p} = \frac{4 \times T \times b}{\pi (ab^3 + a^3b - (a-t)(b-t)^3 - (a-t)^3(b-t))} \quad (2)$$

where T is the maximal torsional moment and I_p is the polar moment of inertia for a hollow ellipse.

Obviously the cross section of the femur of the rat deviates from a hollow ellipse. To estimate the magnitude of this simplification, six rats (Wistar SPF, with mean weight 278 ± 12 g) were investigated. A slice from the middle of the right femur was photographed through a microscope and magnified ($25\times$) (Figure 6). The cross-sectional area was measured by a planimeter. The area and polar moment of inertia were calculated by graphical integration. The area moment of inertia is $\sum x^2 dA$, where dA is the

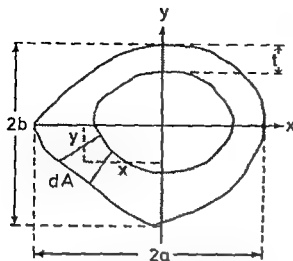


Figure 6 Cross section of the middle part of the rat femur diaphysis. $2a$ and $2b$ represent the major and minor diameters, t the central thickness, x and y the distance of the elemental area dA , from the diameters.

elemental area (Figure 6). The polar moment of inertia is $\sum (x^2 + y^2) dA$.

The femur dimensions were measured using a sliding callipers (accuracy of ± 0.01 mm). The thickness of the femoral cortex (t in the equations (1) and (2)) was measured ventrally in the middle of the femur (Figure 6). The major diameter ($2a$ in the equations) and the minor diameter ($2b$ in the equations) were also measured in the middle of the femur.

The calculated values for the area and polar moment of inertia firstly regarding the femur as a hollow ellipse and secondly by direct measurements of the cross sectional area using planimetry, are given in Table 1.

The mean calculated area moment of inertia is 11 per cent higher than the measured value. The calculated polar moment of inertia is only 2 per cent higher than the measured value. These differences will of course give the corresponding differences in the maximal stress values (see equations (1) and (2)).

To get an impression of the absolute differences in the maximal stress with the measured and the "elliptical moments of inertia, the maximal moment must be known. Therefore, fresh femurs of two groups of rats were tested: one group in bending and the other in torsion. These rats were equivalent to the rats used for moment of inertia measurements. The mean maximal bending and torsional moments were found to be 0.44 Nm and 0.20 Nm respectively. The measured and "elliptical maximal bending and torsional stresses calculated from the equations (1) and (2) are shown in Table 1.

TESTING OF THE APPARATUS

To estimate the accuracy of the apparatus, polished steel rods (diameter 1.70 mm) were tested, ten for bending and eight for torsional strength. At the same rate of testing as the rat femurs, the steel rods did not fracture but exhibited plastic deformation. Therefore the force value at 0.79 radians ($\approx 45^\circ$) deflection was chosen, since this was representative of the force level seen in the bone experiments (Figure 7).

Table 1 Calculated and measured values for the area moment of inertia, bending stress and the polar moment of inertia/torsional stress in the rat femur

	The area moment of inertia (\pm standard deviation)	Max bending stress	The polar moment of inertia (\pm standard deviation)	Max torsional stress
Calculated values	$4.07 \pm 0.60 \text{ mm}^4$	1.62 10^8 N/m^2	$10.63 \pm 0.97 \text{ mm}^4$	$2.91 \cdot 10^8 \text{ N/m}^2$
Measured values	$3.63 \pm 0.52 \text{ mm}^4$	1.82 10^8 N/m^2	$10.45 \pm 1.14 \text{ mm}^4$	$2.96 \cdot 10^8 \text{ N/m}^2$

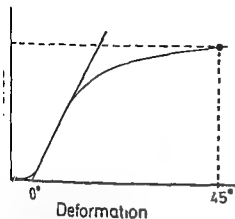


Figure 7 The force deformation curve for the steel in bending (principally the same for torsion) the force value at 45 degrees deflection is marked the deflection is calculated to start where the tangent to the elastic part of the curve crosses the y-axis

The formulas for maximal stress for a solid circular rod (Roark & Young 1975) are

$$\text{Maximal bending stress } \sigma_m = \frac{M \times r}{I} - \frac{4M}{\pi r^3} \quad (3)$$

where r is the radius of the circular rod. The mean bending stress at 45 degrees was $73 \times 10^6 \text{ N/m}^2$ (Standard deviation (s.d.) 0.8 per cent)

$$\text{Maximal torsional stress } \tau_m = \frac{T \times r}{J_p} - \frac{2T}{\pi r^3} \quad (4)$$

The mean torsional stress at 45 degrees was $64 \times 10^6 \text{ N/m}^2$ (s.d. 1.3 per cent)

DISCUSSION

The test system which is described is a simple and accurate method for testing the mechanical properties of both intact rat femurs and fractured femurs in different phases of healing.

The objections to this test system can be divided into mechanical and biological factors.

Beside the limitations of the load transducer, amplifier, chart recorder and

tensile testing machine, some mechanical inaccuracies are known. The weight of the cam on the disc gives tension in the wire, but this is below the sensitivity of the transducer/chart recorder (i.e. less than 0.05 N). Friction both in the ball-bearings and between the bone and the cam on the disc is probably greater, but difficult to estimate. The overall accuracy of the apparatus tested by the steel rods gave, however, a standard deviation of about 1 per cent. This indicates rather accurate measurements, especially since this deviation may partly be caused by variation in the steel rods.

The biological part, i.e. the test bones, is probably the main source of errors in the test system. Angulations in the united fractures will give an unwanted bending moment when tested in torsion, which may result in a reduced measured moment. The magnitude of this error depends on the extent of the angulation. Approximations have to be made in the calculation of the stress from the measured moments and dimensions. Firstly, in the calculations the stress-strain curve is assumed to be linear up to the fracture. Weir et al (1949) found that air-dried rat femur remained elastic only up to three-quarters of the maximal bending stress. Also in the present study, the bones displayed plasticity near fracture (Figure 3). This plasticity may make whole bones considerably stronger (Currey 1969 and Burstein et al 1972). Secondly, bone is not a homogeneous material, but it is penetrated by stress concentrators such as blood vessels, canaliculi and osteocytic lacunae. In addition, the muscle insertions make the surface uneven. Thirdly, the calculations ignore the effect of shear stress, but this error was estimated to be very small (about 0.25 per cent) in another cantilever system (Smith & Walmsley 1959). The fourth assumption is that the cross section of the femur diaphysis is simplified to be a hollow ellipse. In our investigation this simplification is estimated to give a difference of 11 per cent for the area moment of inertia and 2 per cent for the polar moment of inertia. This is in accordance with

Mather (1967) who found that the mean value for the elliptical calculated area moment of inertia of human femurs was 14.5 per cent higher than the measured value.

These inaccuracies in stress calculations are very difficult to avoid but some of them are systematic and will therefore be less important when different groups of bones are compared.

The method of testing the maximal bending moment of the epiphyseal plate and the metaphysis makes it possible to test the growing cartilage and newly produced bone. Both should be important for example when investigating the influence of drugs and hormones on the bone growth.

The test apparatus described is constructed as a modular system. The main parts of it are used both in the testing of bending and torsional properties. It can also be used for tensile strength measurements but bones are normally very seldom subjected to pure tensile stress.

ACKNOWLEDGEMENTS

The authors are grateful to

Johannes Rø MD, Institute for Surgical Research, who initiated the construction of the apparatus described in the present paper. He died suddenly before his work was completed.

James A. Ashton Miller, mechanical engineer, Biomech. Lab., Sophies Mnde Orthoped. Hospital for technical advice.

Financial support from The Norwegian Research Council for Science and the Human x and from Dr. Alexander Mathes Fund.

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JOINT CHANGES AFTER OVERUSE AND PEAK OVERLOADING OF RABBIT KNEES *IN VIVO*

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The effect of overuse and overuse combined with axial peak overloading on the knee joints of living rabbits has been investigated. A specially constructed apparatus was used for this purpose. Physical and biochemical changes are reported and include:

- 1 Early and progressive damage to the articular cartilage surface shown by the scanning electron microscope
 - 2 The presence of an increased amount of prostaglandin E in the synovial fluid
 - 3 A reduction of cyclic 3-5 adenosine monophosphate in the subchondral bone
 - 4 Late changes which were consistent with osteoarthritis
- These changes were found only in the joints subjected to simultaneous overuse and peak overloading.

The results suggest that:

- 1 Cartilage damage and chemical changes in the subchondral bone are simultaneous and are both responsible for eventual degenerative changes
- 2 Frictional overuse alone does not seem to be responsible for the production of osteoarthritis.

Key words: Cyclic 3-5 adenosine monophosphate, overuse, peak overloading, prostaglandin E, scanning electron microscope.

Accepted 21 v 78

Weight bearing joints are subjected to two kinds of stress. One is a shear stress produced by reciprocal friction of the articulating surfaces and the other is produced by axial longitudinal loading. Clinical conditions in which either of these stresses is abnormally increased may induce degenerative changes.

Accordingly, experiments designed to reproduce such changes have involved either modifications of the articular surfaces by chemical or mechanical means (Bennet & Bauer 1937, Trias 1961, Crellin & Southwick 1964, Murray 1964, Hulth et al. 1970) or by increasing the axial longitudinal loading (Simon et al. 1972, Radin et al. 1973).

However, *in vivo*, both stresses are simultaneous and cannot be separated. It was thought important therefore to explore this simultaneous action in the living animal under controlled conditions which allow the separation of these effects.

The present study reports the physical and biochemical changes found in knees of living rabbits after these joints were subjected simultaneously to frictional and loading stress by means of a specially constructed apparatus. One joint was subjected to both stresses. The contralateral one, serving as a control, was subjected to frictional stress only.

EXPERIMENTAL PROCEDURE

White New Zealand adult female rabbits weighing 3–4 kg were used. Skeletal maturity as evidenced by the closure of the lower epiphysis of the femur and the upper epiphysis of the tibia was ascertained roentgenographically. Each rabbit was anaesthetized by open mask Fluothane (ICI) and maintained by the addition of 10 mg/kg of Nembutal (Abbott Laboratories). Under sterile conditions, incisions were made both on the lateral and medial aspects of the thigh and the leg 3 cm away from the knee joint line. Through these incisions two parallel round stainless steel pins were introduced, one into each bone with the aid of a low speed dental handpiece drill. The pin used for the femur was 2.4 mm in diameter and that for the tibia was 2.9 mm (Stainless steel Zimmer, USA). The skin was then closed by silk sutures. A small pad with Betadine was applied around the protruding pins.

The animal was then tied to a specially constructed apparatus. This consisted of a platform (on which the animal could rest with its legs hanging down) and an electric motor (60 watt) which moved a wheel. The upper two pins, one for each femur, were secured to the body of the apparatus. The legs and the feet were connected to the driving wheel by means of a flexible rod. Because of the eccentric attachment of the rod, the rotation of the wheel produced alternative flexion and extension of the knees (Figure 1).

Each revolution of the wheel moved the knee joints from flexion of 80° to full extension. A

forked device which was connected to the driving wheel produced direct impulsive peak overloads to the pin of one of the tibiae. This load was adjusted by a spring to a maximum of 350 g. Therefore, each revolution of the driving wheel caused:

- (a) movement of the two knees from flexion to full extension and
- (b) at the point of full extension of both knees peak overloading was applied to the left tibia.

Because of the rigid fixation of the bones to the apparatus the peak loads exerted on the knee joints were direct and bone conduction. Furthermore, the constant distance of the pins from the knee joint enabled identical experimental conditions regardless of the size of the animals. The forces applied to the joints, either in number of revolutions or the number of peak loadings, must be considered as being above normal. Consequently the abnormal number of flexion/extension movements is defined as over and the axial loadings as peak overloading.

MATERIAL AND METHODS

These are summarized in Table I. Forty rabbits were divided into seven groups. Rabbits of Groups A, B and C were subjected to 30, 60 and 120 minutes at 60 revolutions/minute of the driving wheel (1800, 3600 and 7200 revolutions) respectively. At the end of each of the experiments the animals of the three groups were killed immediately and the articular surfaces of the knee joints were examined by scanning electron microscopy (SEM) and biochemically. In the three rabbits of Group D (7200 revolutions) only the articular menisci and synovial membrane were examined for their prostaglandin (PGE) content immediately after completion of the experiment. Three rabbits of Group E were subjected to the same experimental procedure as those of Group C but were killed 1, 3 and 7 days after completion of the experiment. Only SEM of articular cartilage surface was done in this group.

For the scanning electron microscope examination, the articular surface was unroofed, dissected and fixed at the end of the experiment. Critical point drying was done and then given conductive coats of carbon and according to a method described by Borde & (1974). The specimens were examined and photographed in a Cambridge Stereoscan scanning electron microscope. The pictures of both knees were compared.

The biochemical examinations included analyses for prostaglandin E group (PGE)

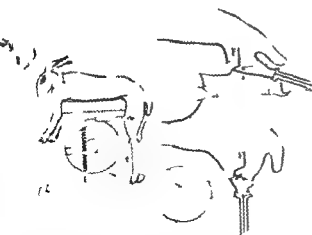


Figure 1. Left: The mode of fixation of the animal on the specially constructed apparatus. Upper right: Flexion of the knee. Lower right: Extension of the knee with the mode of the delivered impact.

Table 1. Summary of the investigation

Group	No of rabbits	Duration of experiment (minutes)	No of revolutions	Examination performed	Biochemical examination				Microscopic and X ray examination		
					cAMP in bone and cartilage	PGC fluid	PGF in synovial meniscus and synovia	STM	Histology	X ray	
A	8	30	1800	Immediate	+	+	+	+	+	+	-
B	8	60	3600	Immediate	+	+	-	+	-	-	-
C	8	120	7200	Immediate	+	+	-	+	-	-	-
D	3	120	7200	Immediate	-	-	+	-	-	-	-
E	3	120	7200	After 1 3 7 days	-	-	-	+	-	-	-
F	6	30 min/day for 5 days	9000	After 75 days	-	-	-	-	+	+	+
G	6	30 min/day for 15 days	27000	After 85 days	-	-	-	-	+	+	+

synovial fluid, the articular cartilage, the menisci and the synovial membrane and (b) the estimation of cyclic 3', 5' adenosine monophosphate (cAMP) in the bones and cartilage. For the former, the knee joints were dissected at the end of the experiments, the synovial spaces were rinsed with 0.5 cm³ of cold 50 mM tris buffer at pH 7.0 and analysed for PGE content by radio-immuno assay (Bauminger et al 1973). The articular cartilage, menisci and synovial membrane obtained from the three rabbits of Group D were homogenized in 50 mM tris EDTA buffer pH 7.0 and analysed for PGE content by the same method.

For the estimation of cAMP, the bones on each side of the knee joints were immediately frozen in liquid nitrogen and cut transversely into 3 mm thick samples and pulverized in liquid nitrogen by a metal piston. After adding the bone powder to distilled water, the mixture was boiled for 5 min in a salt bath (Shanfeld et al 1975). The samples were then further homogenized by an ultrathorax (Tp 18-10).

The cAMP content was estimated in the supernatant by the protein binding assay (Gilman 1970). As the samples from each rabbit were treated identically, the results obtained from the overuse and peak overloaded bones were compared with those obtained from the contralateral bones subjected to overuse only and expressed as the percentage of change.

The rabbits in the groups F and G (six rabbits in each group) served for the estimation of the late changes in the articular cartilage and the bones. In these groups the experiment was run for a period of 30 min at 60 rev/min of the driving wheel each day for 5 and 15 days, 9000 and 27000 revolutions, respectively. In between the experiments the rabbits were allowed to move freely in the cages. Care was taken to protect the protruding pins. Two separate small bandages were applied on each leg in such a way as to allow free movements of the joints. At the end of the experimental period the pins were removed and 10 weeks later, the animals were killed. High resolution roentgenograms of the knee joint were taken and thereafter the joint was examined histologically. After decalcification a sagittal section of the joint was done and stained by haematoxylin eosin.

RESULTS

Scanning electron microscopy (SEM)

The changes in the morphology of the articular surface seen in the knees which were



Figure 2 SEM of articular surface of a femoral condyle after 1 hour of overuse and peak overloading showing both undamaged regions and damaged ones containing debris ($\times 1680$).

subjected to simultaneous overuse and peak overloading consisted of damage in the superficial layer, which was found to be detached exposing the collagenous matrix. These changes occurred only when the experiment lasted at least 1 hour (3600 revolutions and loadings). At that time only a limited area was affected (Figure 2). The affected area was more extensive when the experiment lasted 2 hours (7200 revolutions and loadings) (Figures 3-4). The damage was even more pronounced when the knee was subjected to 7200 revolutions and loadings and examined after 3 or 7 days (Figure 5).

No such changes were seen in the contralateral joint submitted to overuse only (Figure 6).

It may therefore be concluded that peak overloading had long lasting and progressive physical effects, the initial damage giving but an incomplete picture of the later deterioration of the joint surface.

Prostaglandin E group (PGE)

When the knees subjected to simultaneous overuse and peak overloading were examined after 2 hours of exercise (7,200 revolutions and loadings), the synovial fluid was found to



Figure 3 SEM of articular surfaces of a femoral condyle after 2 hours of overuse and peak overloading showing damage and abundant debris ($\times 1500$)



Figure 5 SEM of articular surface taken 7 days after 2 hours of overuse and peak overloading. The cellular layer of the articular surface is detached and the collagenous matrix is exposed. Empty lacunae can be seen ($\times 15,000$)

contain a five-fold increase in prostaglandin E, as compared with the contralateral knee (Figure 7). No significant increase of PGE was found after 30 or 60 min of exercise (1800 and 3200 revolutions and loadings). No significant changes in the amount of prostaglandin were found in the synovial membrane, the articular cartilage or the menisci of both knees.

Cyclic 3-5' Adenosine Monophosphate (cAMP)

The knees subjected to simultaneous overuse and peak overloading showed a reduction of the cAMP content after 60 min of overuse and peak overloading (3600 revolutions), as compared with the other knee. The reduction was more pronounced in

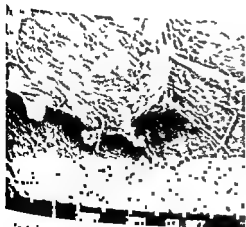


Figure 4 SEM of articular surface of a femoral condyle after 2 hours of overuse and peak overloading showing detail of a semi-detached piece of debris ($\times 10,000$)

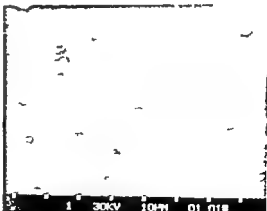


Figure 6 SEM of articular surface of a femoral condyle after 2 hours of overuse only showing a smooth undamaged surface ($\times 1500$)

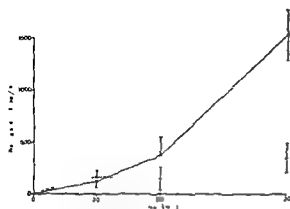


Figure 7 Accumulation of prostaglandins E series in the synovial fluid in overused knees (broken line) and overused and peak-overloaded knees (continuous line)

the subchondral bone and occurred first in the tibia and later in the femur. There were no significant changes, regardless of the number of revolutions, either in the articular cartilage or in the cortical bone (Table 2).

X-ray

Flattening of the epiphysis, small bone cysts and osteophytes were found on the roentgenograms of knees subjected to repeated simultaneous overuse and peak overloading (1800 revolutions and loading per day for 15 consecutive days) (Figure 1). Milder changes were seen when the experiments were repeated for 5 days only. No such abnormality was found in the contralateral knees subjected to overuse only.

Histology

Repeated simultaneous overuse and peak overloading (1800 revolutions and loading per day for 15 days) resulted in cellular degeneration, disturbed arrangement of the cells with cluster formation and fibrillation of the articular cartilage with penetration of the subchondral capillaries into the calcified layer of the cartilage. There was thickening of the subchondral bone with the presence of

Table 2 The cAMP content in different anatomical areas of the knee. The percentages have been calculated according to the following formula:

$$\frac{\text{cAMP left knee} - \text{cAMP right knee}}{\text{cAMP right knee}} \times 100$$

(right knee = overuse only)

(left knee = overuse and peak overloading)

THE cAMP CONTENT OF ARTICULAR CARTILAGE, SUBCHONDRAL, SPONGIOUS AND CORTICAL BONE

Duration of the experiment		30 min	60 min	120 min
		$\bar{x} \pm SE$	$\bar{x} \pm SE$	$\bar{x} \pm SE$
	Cortical bone	0.932 ± 8.87	13.452 ± 11.11	9.8 ± 10.41
	Spongy bone	-2.922 ± 9.04	-2.692 ± 9.04	-32.02 ± 12.44*
	Subchondral bone	+3.252 ± 8.65	-12.862 ± 3.96*	-36.02 ± 2.23*
	Cartilage	+4.102 ± 10.88	-0.432 ± 14.79	-1.252 ± 9.3
	Cartilage	1.902 ± 7.95	7.012 ± 7.45	+7.252 ± 22.3*
	Subchondral bone	+0.06* ± 6.45	-42.92 ± 3.12*	-49.33 ± 6.12*
	Spongy bone	+3.812 ± 11.85	-33.522 ± 7.51*	25.13 ± 4.45*
	Cortical bone	7.93* ± 8.72	+8.062 ± 9.23	+3.0 ± 9.64

* $P < 0.05$

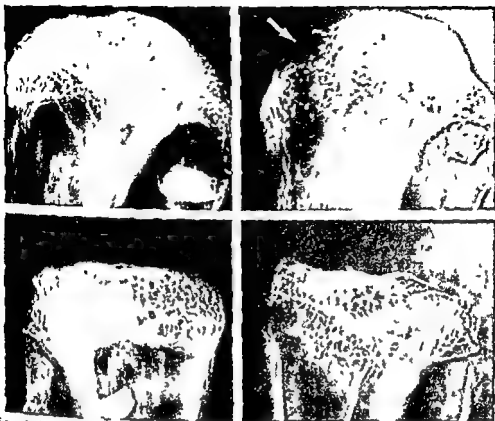


Figure 8 Roentgenograms taken 10 weeks after 15 consecutive days of overuse (at left) and overuse and peak overloading (at right) of the knee. The upper end of the tibia shows flattening of the medial part of the epiphysis with condensation of subchondral bone and cyst formation (arrow) in the peak overloaded area.



Figure 9 Sagittal section of a femoral condyle 10 weeks after 15 consecutive days of overuse and peak overloading showing fibrillated articular cartilage which becomes progressively thinner from left to right. The tidemark has advanced into the subchondral bone and there is increased subchondral vascularity ($\times 80$).



Figure 10 Sagittal section of a femoral condyle 10 weeks after 15 consecutive days of overuse and peak overloading showing disorganization of cartilage cells and hypocellularity in the radial zone with empty lacuna. The tidemark is broken and penetrated by blood vessels from subchondral bone. The subchondral bone is thick and new lamellar bone has formed ($\times 300$).



Figure 11 Articular cartilage from an overused knee 10 weeks after 15 days of exercise showing a normal arrangement of the cartilage in the various zones. The tidemark is intact and there are no changes in the subchondral bone ($\times 300$)

lamellar bone parallel to the articular surface (Figures 9, 10). These changes, consistent with the pattern of osteoarthritis, were not found in the contralateral joint subjected to overuse only (Figure 11).

DISCUSSION

The fact that the observed changes occurred in knees subjected to simultaneous overuse and peak overloading but not in those subjected to overuse only permits the conclusion that it is the added peak overloading which is responsible for their occurrence. These changes are twofold: early physical and biochemical changes in the articular cartilage, the subchondral bone and synovial fluid and late changes in the articular cartilage and subchondral bone consistent with osteoarthritis.

With regard to the physical changes in the articular cartilage, there are three points which merit some emphasis —

1. The existence of a threshold below which no changes occur.
2. The direct relation of the extent of damage to the duration of the insult.
3. The progressive deterioration after cessation of the insult. It may be presumed that the last two in particular may have an influence on the

appearance of the late osteoarthritic changes.

Increased amounts of PGE have been found in the synovial fluid of patients with septic arthritis and active rheumatoid arthritis (Velo et al 1973, Robinson & Levine 1974). Synovial cells derived from rheumatoid patients synthesize large quantities of PGE *in vitro* (Robinson et al 1975b, Dayer et al 1977). The high levels of prostaglandins in the joints of such patients are believed to be one of the factors leading to cartilage destruction and bone resorption (Eisenbarth & Lebovitz 1974, Robinson et al 1975a, Dietrich & Raisz 1975). However, the role of prostaglandins in osteoarthritis is not yet established. Our results may suggest that prostaglandins have an important role in the pathogenesis of osteoarthritis as a result of repetitive overloading. Furthermore, the relative effectiveness in patients with osteoarthritis of anti-inflammatory drugs such as aspirin and indomethacin, which are potent prostaglandin synthetase inhibitors (Vane 1971, Ferreira et al 1971), can be explained on this basis.

The changes in cAMP content in the subchondral bone are more difficult to interpret. Cyclic cAMP is thought to be the second messenger in regulating intracellular functions as a consequence of the action of external stimuli, hormones in particular (Sutherland et al 1965). Lately it was suggested that cAMP may act as a mediator of the mechanical stimuli in bone and cartilage (Rodan et al 1975, Davidovitch & Shanfield 1976, Harel et al 1977). In addition, intimate correlations exist between cAMP levels and proliferative activity of various cell types. Reduction in cAMP concentration was observed during mitotic activity of fibroblasts, bone marrow and other cells (Otten et al 1971, Tien et al 1973, Herbert 1973, Oler et al 1973, Tell et al 1973). The reduction of the cAMP level found in the subchondral bone may express either a reaction to the mechanical stimulus or an increased mitotic activity. However, the reduction was specifically in the subchondral bone and not in the cartilage or cortical bone.

This observation confirms the concept developed by Radin et al (1972, 1973) in which impact loading produced rapid changes in the subchondral bone, leading to bone stiffening through microfractures or bone resorption and new bone formation (Pugh et al 1974). This subchondral remodelling is assumed to initiate secondary changes in the articular cartilage (Johnson 1962).

The results of our experiments do not allow us to draw definite conclusions as to the initial factor. It seems reasonable to assume that the damage to the cartilaginous surface and the biochemical changes in the subchondral bone may be simultaneous and that their cumulative effects lead to late osteoarthritic changes such as those seen in the groups of animals killed some time after completion of the experiments.

ACKNOWLEDGEMENTS

This work was supported by a grant from the Joseph W. Eiser fund for research. The assistance of Dr Nazam Bariv and Barbara Slater is gratefully acknowledged.

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EFFECTS OF OXYTETRACYCLINE ON THE MECHANICAL PROPERTIES OF BONE AND SKIN IN YOUNG RATS

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The influence of the tetracycline antibiotics on growing bones has been disputed. In the present study, 58 young male rats were given intraperitoneal injections twice a day for 2 weeks, half of the rats received oxytetracycline and the other half placebo. The concentration of oxytetracycline in plasma was comparable with therapeutic levels in man. Compared with the control animals, the oxytetracycline rats had at the end of the medication period, a significantly lower weight (7 per cent), shorter bones (1-2 per cent), lower bending strength of both the tibia diaphysis (9 per cent) and the distal femur metaphysis (22 per cent) and even lower tensile strength of intact (17 per cent) and sutured (27 per cent) skin. The effect of oxytetracycline seems to be reversible as no differences between the two groups could be detected 1-3 weeks after the end of medication.

Key words: bones, mechanical properties, oxytetracycline, plasma concentration, rats, skin, tensile strength, tetracycline.

Accepted 11 iv 78

It is well established that tetracycline antibiotics are deposited in developing teeth, leading to discolouration and enamel hypoplasia. These antibiotics are also known to deposit in growing bones, but their effect on bones is disputed. Reduced bone growth (Cohlén et al. 1963, Yen & Shaw 1972) and increased bone fragility (Gudmundson 1971) have been observed, but there have also been reports of no impairment of growing bones by the tetracyclines (Chu et al. 1963, Gruden 1973). To our knowledge, the effect of these antibiotics on the mechanical properties of skin has so far not been investigated.

The purpose of the present study in rats was to assess the effect of oxytetracycline on

MATERIALS AND METHODS

Fifty-eight outbred male Wistar/Ki/Møl SPF rats were used. At the start of the experiments, the rats were 20 to 21 days old, weighing from 32 to 37 g. Five animals were kept in each cage and given water and Norwegian standard diet for rats *ad libitum*. The rats were divided in two weight-matched groups of 29 animals: one oxytetracycline-treated and the other control.

The oxytetracycline-treated rats received 2.8 mg oxytetracycline (Terramycin[®], Intravenous, Pfizer) in 0.5 ml water in intraperitoneal injections every twelfth hour for 14 days. For practical reasons, the amount of medicine given to each animal was constant throughout the medication period. In the middle of the period, 49 mg/kg was given twice a day. The control animals received corresponding injections of the vehicle.

The oxytetracycline concentrations were determined by the paperdisc method of AB-biodisk (Stockholm, Sweden) utilizing *Bacillus cereus* (ATCC 11778) as test organism and

1. Weight gain and longitudinal bone growth.
2. Mechanical properties of a) Bones, b) Wounded and intact skin.

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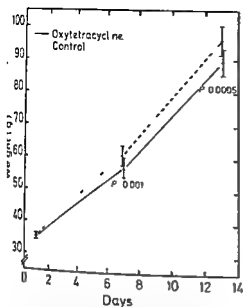


Figure 2 The weight gain in the oxytetracycline and in the control rats in the medication period (Median with 25 and 75 fractiles)

RESULTS

On the fifth and twelfth day of medication the plasma concentration of oxytetracycline was measured 2, 6 and 12 hours after the intraperitoneal injections. The results are shown in Table 1.

The weight of the rats increased six times during this 5 week experiment, from 35 to 215 g. During the first 2 weeks, i.e., in the medication period, the growth was however, significantly lower for the oxytetracycline than for the control rats (Figure 2). In the

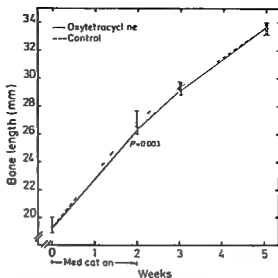


Figure 3 The longitudinal growth of the right tibia in the oxytetracycline and in the control rats (Median with 25- and 75 fractiles)

last 3 weeks of the experiment there was no difference in weight between the two groups, as the oxytetracycline rats caught up with the control rats a few days after the end of the medication period.

Principally the same experience was gained when studying the length of the bones. At the end of the medication period both tibia and femur were significantly shorter in the oxytetracycline than in the control group. No difference was found after 3 and 5 weeks (Figure 3).

A corresponding difference was found in the bending strength of the bones in the two groups. The distal femur metaphysis of the

Table 1 The plasma concentration of oxytetracycline on the fifth day (5 rats) and on the twelfth day (4 rats) of the medication (Median with 25 and 75 fractiles)

Day of medication	Dose mg/kg/12h	Plasma concentration (μ g/ml)		
		2h after injection	6h after injection	12h after injection
5th	51	8.0 (8.0-9.3)	2.4 (1.9-2.6)	< 1.0
12th	31	6.0 (5.3-6.8)	0.8 (0-1.6)	< 1.0

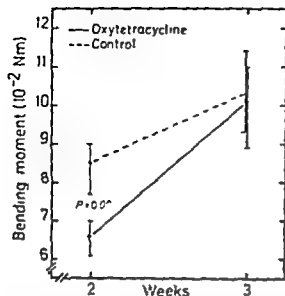


Figure 4 The bending moment necessary to produce fracture in the distal right femur metaphysis (3 mm proximal to the epiphyseal plate) in the oxytetracycline and in the control rats (Median with 25 and 75 fractiles)

oxytetracycline rats was 22 per cent weaker than the metaphysis of the control rats at the end of medication while no difference was observed later (Figure 4). After 2 weeks the bending strength in the middle of the tibia was also significantly less (9 per cent) in the oxytetracycline than in the control group and once again there was no difference after 3 and 5 weeks.

Oxytetracycline was also found to influence the mechanical properties of skin. The tensile strength of sutured skin specimens was 27 per cent less ($P=0.02$) in the oxytetracycline than in the control animals at the end of medication. Also this parameter was equal in the two groups 1 and 3 weeks later. The intact skin specimens from the oxytetracycline group were about 17 per cent weaker than the specimens from the control group both at 2 and 3 weeks, but no difference was found at 5 weeks (Figure 5).

DISCUSSION

In the present study oxytetracycline medication caused reduced weight gain, reduced

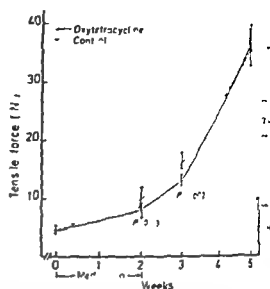


Figure 5 The tensile force necessary to pull over the intact skin specimens from the oxytetracycline and from the control rats (Median with 25 and 75 fractiles)

longitudinal bone growth, increased bone fragility and reduced skin tensile strength.

The oxytetracycline dosage may perhaps seem to be a point of contention in this investigation. The amount given in mg/kg/day is true enough two to five times higher than the recommended maximum human dose (30 mg/kg/day). The plasma concentration is, however, by no means above human therapeutic levels. A single intravenous injection of 75 mg/kg oxytetracycline in man gives serum concentrations after 1–2 hours of 6–10 µg/ml, after 5–7 hours 4–5 µg/ml and after 11–12 hours still 2–3 µg/ml (Orten et al. 1975). These concentrations are comparable to those in the present experiment and as 75 mg/kg is well within the recommended human dosage, the concentrations in the present study correspond to human therapeutic levels. Comparing the dosage in the present investigation with that in others, however, is difficult as the medicine is administered in different ways and the plasma concentration of tetracycline is reported in few publications.

The influence of oxytetracycline in the present study seems to be reversible as no difference in growth or in strength could be

ated 1 week after the cessation of medication, except for the tensile strength of intact skin from the oxytetracycline rats. This parameter was, however, equal in the two groups 3 weeks after the end of medication. A considerable inhibition of bone growth of oxytetracycline was also reported by Cohlan et al. (1963) in premature infants and by Yen & Shaw (1973) in young monkeys. Gudmundsson (1971), however, observed increased fragility of femur and tibia for 90 days after only 1 week of intramuscular injections of oxytetracycline (10 mg/kg/day).

The possibility may be considered that the reduced growth observed in the oxytetracycline rats during the medication was a sequence of impaired intestinal function, caused either by disturbance of intestinal flora or by an inflammatory reaction in the peritoneal cavity after the oxytetracycline injections. In accordance with the latter, at the end of medication, the peritoneum was found to be more reddish in the oxytetracycline than in the control rats, but no signs of inflammation were observed later in either group. However, Cohlan (1963) and Yen & Shaw (1972) also reported reduced growth and they did not use intraperitoneal administration of medicine.

At the end of medication the femur and tibia in the oxytetracycline rats were shorter - 1 and 2 per cent, respectively - than in the bones in the control rats while the tensile strength of the tibia diaphysis was reduced by 9 per cent and that of the distal femur metaphysis by 22 per cent compared with the bones of the control animals. This may indicate that the bone strength is reduced to a greater extent than the longitudinal bone growth. Why then would the reduction in bone strength be more pronounced in the femur metaphysis than in the tibia diaphysis? The explanation may be found in the mode of growth of the long bones. As the longitudinal growth of the tibia and femur takes place mainly in the epiphyseal plates near the knee and at the proximal end of the bone, the bone growth during the medication was about 6 mm, all the tested metaphyseal bone

material (3 mm proximal to the epiphyseal plate) was produced under the influence of oxytetracycline. In the tibia diaphysis, however, only parts of the tested bone material were made under oxytetracycline influence, viz., the shell of periosteum derived bone. If oxytetracycline really causes production of a weaker bone material it would be expected that the metaphyseal bone would be more affected than the diaphyseal bone, as the former is entirely produced under the influence of oxytetracycline while the latter only partly.

Also the reduction in the tensile strength of both intact and sutured skin (17 and 27 per cent, respectively) from the oxytetracycline rats appears to be greater than the general growth inhibition (weight difference of 0 per cent in the two groups) can explain.

In what way the oxytetracycline hypodermis the mechanical properties of both bone and skin remains unanswered. As collagen is the dominant organic component both in bone and skin, the influence of oxytetracycline on the biosynthesis and maturation of collagen seems extremely interesting in this context.

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CONTENT AND SYNTHESIS OF NUCLEIC ACIDS IN THE CARTILAGE IN CHONDROMALACIA PATELLAE

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The content and the synthesis of nucleic acids in chondromalacian, osteoarthritis and normal cartilage was compared. The chondromalacian cartilage differed from osteoarthritis in that the content of nucleic acids was less. Also, the cell density was less in chondromalacian than in normal cartilage as opposed to previous findings in osteoarthritis. The synthesis of

tearthritis cartilage

Key words: chondromalacia patellae, articular cartilage, autoradiography, nucleic acids

Accepted 15 iv 78

Chondromalacia patellae is defined as a degenerative condition of the articular cartilage of the patella. Usually, it is seen in young adults but it may also occur in later life. The etiology is debatable. Trauma, incongruity and nutritional causes have been discussed. There are numerous biochemical studies of osteoarthritis, whereas studies of chondromalacia patellae have been noticeably few. In an earlier investigation (Shoji et al 1974) no differences in the DNA content compared with normal articular cartilage were found, nor any differences in the content of hexosamine, non-collagenous protein, acid phosphatase or beta-glucuronidase. However, the content of Cathepsin B was found to be significantly elevated in both chondromalacia and osteoarthritis. Owing to these results the authors suggested that chondromalacia seemed to be a disease developing into osteoarthritis.

The purpose of the present study was to compare parameters of nucleic acid content and synthesis in normal joint cartilage, chondromalacian cartilage and the cartilage of joints with osteoarthritis.

MATERIAL AND METHODS

Samples of the patellar lesions in 28 patients with chondromalacia patellae of grade I-III (Outerbridge 1961) were obtained in conjunction with surgery. The age range of the patients was 15-45 (average 28). In nine patients, cartilage was also taken from macroscopically normal parts of the patellar joint surface and in eight from a non-weight bearing part of the femoral condyles also of normal appearance. In addition, cartilage biopsies were obtained from 19 individuals with the same range of age in conjunction with arthrotomies for removal of ruptured semilunar cartilages. In none of the latter patients were there any macroscopic signs of degenerative joint disease including chondromalacia patellae. Finally, cartilage samples were obtained from the femur condyles in eight patients with osteoarthritis of the knee in conjunction with surgical reconstruc-

tion of the joint. In these cases the cartilage was taken from the weight-bearing part of the femur condyle joint surface. The age of this latter group ranged from 29 to 69 with an average of 53. The 29-year-old was a man with post-traumatic osteoarthritis of the knee, otherwise the osteoarthritis was classified as primary.

The specimens were divided into two pieces, one for biochemical investigation and one for histologic and autoradiographic studies. They were immediately placed in 10 ml of Eagle's solution at 37°C containing 50 μ Ci 3 H thymidine or 3 H-uridine and shaken for 4 hours.

The specimens for the histologic-autoradiographic study were washed in physiologic saline solution and fixed in 10 per cent neutral, buffered formalin, decalcified in EDTA and embedded in paraffin. The histologic specimens were stained with hematoxylin-eosin, with Safranin-O and toluidine blue.

In seven of the patients with chondromalacia patellae the abundance of chondrocytes was estimated in a) areas of chondromalacia b) patellar articular cartilage of normal appearance and c) condylar cartilage also of normal appearance. In each sample, five fields (0.5 \times 0.5 mm) were selected at random and counted. The average variation within each sample was 11 per cent (c/v).

In all but the samples from osteoarthritis cases, autoradiographs of routine histologic sections, 5 μ thick, were prepared according to the dipping method with Ilford K2 liquid emulsion. After 2 and 4 weeks exposure the autoradiographs were developed in Gevart X-ray developer G 230 and fixed in Gevart X-ray fixer G 305. The sections were stained through the emulsion with Mayer's hematoxylin. The specimens for the biochemical study were placed in acetone after shaking. The material was weighed (dry weight). The cartilage was placed in a mortar covered with liquid nitrogen and pulverized. It was then homogenized in 6 ml 10 per cent TCA (trichloroacetic acid) and the acid soluble nucleotides were separated by centrifugation. The precipitate was washed twice each time with 6 ml TCA. The insoluble residue was treated with 5 ml of 0.3 M potassium hydroxide for 18 hours at 37°C to hydrolyze RNA, which was thereby brought into solution. The solution was adjusted to pH 7 by the addition of 70 per cent perchloric acid. Five ml of 5 per cent TCA was added to the neutral solution. This resulted in precipitation of protein and DNA which were separated from the solution by centrifugation and washing of the precipitate three times, each time with 5 ml of 5 per cent TCA.

RNA and DNA in the separated fractions were determined with the orcinol reaction (Mejbaum 1939) and the Cerenkov procedure (Cerenkov 1952) respectively. The separation of RNA and DNA was checked in all experiments by applying both reactions to the RNA as well as to the DNA fraction. The determinations were carried out in duplicate and the average used for further calculation.

Each sample was assayed separately for radioactivity (3 H thymidine or 3 H-uridine) after suspension in 10 ml of Instagel (Packard), using two-channel Packard Tricarb liquid scintillation spectrometer. The results were recorded as counts per milligram of dry weight per minute.

RESULTS

No labeled chondrocytes or microscopic changes were found in the control specimens. In the chondromalacian cartilage degenerative changes were seen with flaking of the superficial layer and sometimes fibrillation down to the columnar layer (Figure 1). Sometimes the superficial and also the transitional layers were loose with sparse staining of the matrix. In some slides, fibrillation of the columnar layer as well as chondrocyte death and clustering were found similar to the findings in osteoarthritis, and in some blister formation in the superficial and transitional layers (Figure 2). After staining with Safranin-O and toluidine blue the matrix was less stained in the slides with degenerative changes. The chondrocytes were significantly less abundant in the chondromalacian cartilage as compared with normal patellar and condylar cartilage (Table 1). No labeled chondrocytes were found in the cartilage from patients with chondromalacia.

The content of DNA was significantly decreased in the chondromalacian cartilage as compared with normal cartilage (Table 2). Similar tendencies were found when the chondromalacian cartilage was compared with normal cartilage from the same patella or with femoral condyle cartilage from the same joint (Tables 4 and 5). The DNA content was significantly greater in osteoarthritis cartilage than in chondromalacian cartilage (Table 8) but not quite significantly



Figure 1 Section of chondromalacian cartilage in fibroblast layer. Note the scarcity of chondrocytes (Objective $\times 63$ hematoxylin-eosin)



Figure 2 Section of chondromalacian cartilage with blister formation in the superficial and transitional layers (Objective $\times 63$ hematoxylin-eosin)

Table 1 Number of chondrocytes per mm^2 of chondromalacian cartilage as compared with normal patellar and condylar cartilage

Chondromalacian cartilage			Normal patellar cartilage			Normal condyle cartilage		
n	av	s.d.	n	av	s.d.	n	av	s.d.
7	164 \pm 35		7	296 \pm 84		7	306 \pm 66	
	0.01 > P > 0.001			P > 0.001			P > 0.1	

Table 2 Nucleic acid content in patella cartilage of patients with chondromalacia patellae (chondromalacia) and in non-weight bearing condylar cartilage obtained in conjunction with meniscectomy (control)

		$\mu\text{DNA/mg}$	$\mu\text{RNA/mg}$	$\mu\text{RNA}/\mu\text{DNA}$
chondromalacia	(n = 28)	2.5 \pm 1.3	4.5 \pm 2.4	2.6 \pm 2.9
	(n = 19)	4.0 \pm 2.0	7.3 \pm 3.2	2.2 \pm 0.8
control		0.01 > P > 0.001	0.01 > P > 0.001	—

Table 3 Nucleic acid synthesis in patella cartilage of patients with chondromalacia patellae (chondromalacia) and in non-weight bearing condylar cartilage obtained in conjunction with meniscectomy (control)

	CPM DNA/ mg	CPM DNA/ μDNA	CPM RNA mg	CPM RNA/ μDNA	CPM RNA/ μRNA
chondromalacia	(n = 28)	88 \pm 57	36 \pm 26	695 \pm 450	410 \pm 420
	(n = 19)	65 \pm 33	19 \pm 11	1217 \pm 689	381 \pm 238
control		0.1 > P > 0.05	0.05 > P > 0.01	0.01 > P > 0.001	—

Table 4 Nucleic acid content in the cartilage of chondromalacian lesions (chondromalacia) and in cartilage of normal macroscopic appearance (control) from the same patella

Cartilage		$\mu\text{DNA/mg}$	$\mu\text{RNA/mg}$	$\mu\text{RNA}/\mu\text{DNA}$
Chondromalacia	(n=9)	2.9 ± 1.2	6.1 ± 1.8	2.5 ± 0.9
Control	(n=9)	4.8 ± 2.2	8.5 ± 2.9	2.0 ± 0.9
		$0.05 > P > 0.01^*$	$0.05 > P > 0.01^*$	—

* *t* test of pairs.

Table 5 Nucleic acid synthesis in the cartilage of chondromalacian lesions (chondromalacia) and cartilage of normal macroscopic appearance (control) from the same patella

Cartilage		CPM DNA/ mg	CPM DNA/ μDNA	CPM RNA/ mg	CPM RNA/ μDNA	CPM RNA/ μRNA
Chondromalacia	(n=9)	134 ± 57	49 ± 35	1205 ± 428	537 ± 237	216 ± 53
Control	(n=9)	131 ± 100	27 ± 15	1089 ± 232	263 ± 72	166 ± 101
		—	$0.1 > P > 0.05^*$	—	$0.01 > P > 0.001^*$	—

* *t* test of pairs.

Table 6 Nucleic acid content in the patella cartilage of patients with chondromalacia patella (chondromalacia) and in cartilage of normal macroscopic appearance (control) from the femoral condyle of the same joint

Cartilage		$\mu\text{DNA/mg}$	$\mu\text{RNA/mg}$	$\mu\text{RNA}/\mu\text{DNA}$
Chondromalacia	(n=8)	2.6 ± 0.7	6.1 ± 1.9	2.6 ± 0.9
Control	(n=8)	4.2 ± 2.1	9.0 ± 4.8	2.6 ± 1.7
		$0.1 > P > 0.5$	$0.2 > P > 0.1$	—

Table 7 Nucleic acid synthesis in the patella cartilage of patients with chondromalacia patella (chondromalacia) and in cartilage of normal macroscopic appearance (control) from the femoral condyle the same joint

Cartilage		CPM DNA/ mg	CPM DNA/ μDNA	CPM RNA/ mg	CPM RNA/ μDNA	CPM RNA/ μRNA
Chondromalacia	(n=8)	131 ± 60	52 ± 36	1198 ± 457	567 ± 234	210 ± 68
Control	(n=8)	128 ± 69	32 ± 15	1175 ± 211	327 ± 125	513 ± 1107
		—	$0.2 > P > 0.1^*$	—	$0.05 > P > 0.01^*$	—

* *t* test of pairs.

Table 8 Nucleic acid content in the cartilage from the femoral condyle of patients with osteoarthritis of the knee (osteoarthritis) and in chondromalacian lesions of patients with chondromalacia patellae (chondromalacia)

Cartilage		μ DNA/mg	μ RNA/mg	μ RNA/ μ DNA
Osteoarthritis	(n=8)	57 \pm 21	123 \pm 34	26 \pm 13
Chondromalacia	(n=28)	25 \pm 13	45 \pm 24	26 \pm 29
		0.001 > P	0.001 > P	—

Table 9 Nucleic acid synthesis in the cartilage from the femoral condyle of patients with osteoarthritis of the knee (osteoarthritis) and in chondromalacian lesions of patients with chondromalacia patellae (chondromalacia)

Cartilage	CPM DNA/ mg	CPM DNA/ μ DNA	CPM RNA/ mg	CPM RNA/ μ DNA	CPM RNA/ μ RNA
osteoarthritis (n=8)	222 \pm 264	31 \pm 14	1355 \pm 562	271 \pm 144	124 \pm 81
chondromalacia (n=28)	88 \pm 52	36 \pm 26	695 \pm 450	410 \pm 420	152 \pm 80
	0.05 > P > 0.01	—	0.01 > P > 0.001	—	—

increased in osteoarthritis cases as compared with the 19 controls (0.1 > P > 0.05) (Tables 2 and 8).

The RNA content was reduced in chondromalacian cartilage both in comparison with the control patients and with the cartilage of normal appearance in the same joint. When corrected for the DNA content, however, there were no differences in the RNA concentrations (Tables 2, 4 and 6).

The DNA synthesis, related to the DNA concentration, was significantly increased in chondromalacian cartilage as compared with control cartilage (Table 3). This tendency was contradicted by the comparison with cartilage samples from the same joint (Tables 2 and 7). However, per unit tissue, the DNA synthesis did not significantly differ between control and chondromalacian cartilage and was identical when a comparison was made between normal and chondromalacian cartilage in the same joint (Tables 3, 5 and 7). In comparison with osteoarthritis there was no difference in DNA synthesis except when corrected for the amount of tissue (Table 9). When corrected for the DNA content there was no difference.

The RNA synthesis was about half in chondromalacia as compared with controls when related to the amount of tissue (Table 3). However, when corrected for the DNA concentration, there was no significant difference. When, on the other hand, the data were compared between chondromalacian cartilage and cartilage of normal appearance within the same joint there was a significant increase. To summarize chondromalacian cartilage demonstrated the highest rate of synthesis of RNA, whereas osteoarthritis in this study represented the lowest value with the control data in an intermediate position.

DISCUSSION

The histological changes in osteoarthritis are well known and have been described by Collins (1949) and others.

In chondromalacia patellae, microscopic degenerative changes of the articular cartilage were found similar to those in osteoarthritis, with flaking of the cartilage surface and fibrillation (Figure 1) sometimes down to subchondral bone. As an expression of the

degeneration the ground substance was often less stainable with Safranin-O and toluidine blue in chondromalacia thus indicating a loss of glycosaminoglycans from the cartilage matrix changes similar to those in osteoarthritis

Goodfellow et al (1976) described fasciculation of the cartilage of the patella in young people suffering from intractable patello-femoral pain. They also found an intermediate stage (between fasciculation stages 1 and 2) with blistering of the cartilage. This was confirmed in our investigation where blistering was found especially in the superficial and transitional layers (Figure 2).

In earlier investigations, an increased thickness of the cartilage was found in human osteoarthritis (Meachim & Collins 1962). In comparison with normal articular cartilage from the patella or from the femoral condyle there were less chondrocytes in chondromalacian cartilage. According to Freeman (1973) there is an approximately inverse relationship between cell density and cartilage thickness. We could not find any difference between normal cartilage from the patellae and cartilage from the femoral condyle either histologically or biochemically. In earlier investigations it has been shown that mitoses of the chondrocytes indicating a higher DNA synthesis are found in degenerated articular cartilage from humans and animals (Hulth et al 1972, Telhag 1972). In chondromalacia patellae no thymidine-labeled chondrocytes were seen either as single chondrocytes, or in so-called clusters. In osteoarthritis the DNA synthesis is increased (Mankin & Lippiello 1970, Mankin et al 1971). In the present study the same was found to occur in chondromalacian cartilage but not to a sufficient extent to label the chondrocytes.

Shoji et al (1974) found that the amount of DNA in chondromalacian cartilage compared with normal cartilage was unchanged. In the present investigation a significantly decreased content of DNA was found in chondromalacian cartilage. This is in agreement with the decreased chondrocyte density. As reported in the past (Mankin & Lippiello 1970, Telhag &

Gudmundson 1972) the DNA content in osteoarthritis as compared with normal cartilage is unchanged but in the present study there was a significant increase in osteoarthritis cartilage compared with chondromalacian.

The RNA content has not previously been determined in chondromalacian cartilage. We found a reduced quantity of RNA per amount of tissue as compared with normal cartilage. In relation to the DNA content the quantity of RNA was unchanged. This is in agreement with the reduced cell density in chondromalacian cartilage found histologically.

In a recent study the RNA synthesis in human osteoarthritis cartilage was not found to differ significantly from that of normal articular cartilage (Mankin & Lippiello 1970). Mankin & Laing (1967) demonstrated a decreased synthesis of RNA in osteoarthritis cartilage from dogs which is in agreement with the findings in rabbits by Telhag & Gudmundson (1972). In the present study no significant difference was found in the RNA synthesis in chondromalacian cartilage as compared with normal cartilage. When comparing cartilage from chondromalacian lesions and cartilage of normal appearance within the same joint there was an increase in the synthesis.

In the present investigation some factors indicate that chondromalacia patellae is a different disease from osteoarthritis viz., the reduced chondrocyte density, the absence of thymidine labeled chondrocytes and the concentration of nucleic acids which is low as compared with normal articular cartilage as well as osteoarthritis cartilage.

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OSTEOMYELITIS AFTER OPERATIVE FRACTURE TREATMENT

A Report of 62 Cases Treated with Radical Surgery and Lincomycin (Lincocin®)

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During the years 1967-1975 a total of 62 patients were treated for postoperative osteomyelitis. The lower extremities had been fractured in 49 per cent of the cases and 54 per cent were closed injuries. The fractures, mostly caused by traffic accidents and falls, had been immobilized by pins in 30 and by intramedullary nails or pins in 25 patients.

Staphylococcus aureus was cultured in 80 per cent, 68 per cent of them were resistant to penicillin, but in 84 per cent the organisms were highly lincomycin sensitive and only three patients with four osteomyelitic lesions presented lincomycin resistance.

The treatment consisted chiefly of sequestrectomies and saucerizations supported by 3-12 months of lincomycin treatment. In 30 operations a closed irrigation-suction technique was used perfusing the wound with lincomycin solution. Stable implants should be left in place until the fracture is clinically solid whereas unstable osteosyntheses should be replaced by rigid internal or extraskelctal fixation.

At follow-up, the results were judged as good in 74 per cent (air 8 per cent and poor 11 per cent). The amputation rate was 13 per cent.

Plates should not be used in the treatment of comminuted tibial fractures with considerable soft tissue damage.

Key words: post-traumatic osteomyelitis, operative procedures, closed irrigation-suction drainage, lincomycin treatment, osteosynthesis of fractures, osteomyelitis, predisposing factors.

Accepted 25.11.78.

Osteomyelitis following fracture surgery implies a serious complication which prolongs the treatment and considerably increases the disability of the patient.

This report concerns the results and some essential points in the treatment of chronic osteomyelitis after fracture surgery. It also reflects some of the features of the primary treatment which favour the development of osteomyelitis. Eighteen patients included in

the present series have been reported earlier.¹ (Paus 1971).

MATERIAL AND METHODS

During the period 1967-1975, a total of 62 patients, 51 men and 11 women with 63 surgically treated fractures were treated for postoperative osteomyelitis at Martina Hansens Hospital. Hip infections after osteosynthesis for

coral neck and pertrochanteric fractures were excluded from the material.

There was a preponderance of men between 20 and 50 years of age (mean age 38 years) with traffic and occupational accidents while the women (mean age 48 years) usually sustained fractures at an older age as the result of a fall.

The accidents could be classified as 28 road accidents, 21 falls, 7 occupational accidents, 4 sports injuries and 2 shooting injuries.

In agreement with other publications the osteomyelitis was located in the femur and the tibia in 89 per cent of the cases (Table 1).

The records and X-rays from the hospitals where the primary treatment was given were

reviewed with particular attention being paid to the type of osteosynthesis (Table 2) and the postoperative occurrence of osteomyelitis (Table 3). Half of the operations were performed as emergencies within 24 hours of the accident, the rest were delayed from 2-30 days. Table 3 reveals that half of the infections developed within 2 weeks and 40 per cent were delayed more than 2 months.

Seventy-five per cent of the fractures were associated with extensive damage to skin and soft tissues, and 33 per cent of the operations involved preoperative technical difficulties. Half of the fractures were stable postoperatively, 70 per cent of the closed and 32 per cent of the open fractures, respectively.

Table 1 Localization and type of fracture in 63 fractures with osteomyelitis after osteosynthesis

	Closed	Open		
proximal femur	14	10	} 89 per cent	
distal femur	11	15		
tibia	3	1		
fibula	1	1		
coral neck	3		} 11 per cent	
proximal shaft		1		
distal shaft		1		
ulna	2			
	34	29		
	(54 per cent)	(46 per cent)		

Follow-up examination

All the 62 patients were examined clinically and roentgenologically 3 months - 10 years after the last operation, the average observation period being 6.5 years. Two patients with mainly ischaemic crural problems were followed for only 9 months whereas the remaining 60 patients were observed for a period of more than 2 years.

One patient with a previously infected malleolar fracture died from cardiac failure in 1970; the postmortem examination revealed a poorly healed osteomyelitis. This patient is included in the material.

At follow-up, the state of the patients was classified according to the following criteria:

Good No clinical or roentgenological signs of osteomyelitis over the previous 2 years, ≤ 10 per cent anatomical invalidity, normal sedimentation rate, normal or slightly reduced function, normal working ability.

Table 2 Primary fracture treatment in 63 fractures (62 patients) complicated by osteomyelitis

		Number	Per cent
intramedullary nail		30	48
+ Cerclage	8		
+ Parham's band	4		
distal femur	2	14	22
+ Cerclage	7		
+ Parham's band	2		
+ Screws	1		
proximal femur	1	11	17
+ Cerclage	3		
distal femur or Parham's band	2	5	8
distal femur + bone transplant		3	3
		1	2

Table 3 Time of manifestation of osteomyelitis in 63 fractures treated with osteosynthesis

	Number	Per cent
< 2 Weeks	33	52
3rd Week—1st Month	5	8
2nd Month—6th Month	19	30
> 1/2 Year	6	10

Fair Recurrence of osteomyelitis with or without minimal drainage, 10–25 per cent anatomical invalidity, reduced function

Poor Persistent drainage, pseudarthrosis, amputation of femur or tibia, > 25 per cent anatomical invalidity, considerably reduced function, disability insurance only owing to sequelae following osteomyelitis.

The groups "Good" and "Fair" constituted satisfactory results. All the criteria for a classification of "Good" needed to be fulfilled before the patient was placed in this group while only one was necessary in the groups "Fair" and "Poor"

TREATMENT OF OSTEOMYELITIS

The mean duration of osteomyelitis was 2 years (range 1 month – 23 years), and on admission to our department 90 per cent of the infections presented discharging fistulas whereas the remaining were temporarily dry. After discontinuation of any antibiotic drug and no medication for about 1 week, new specimens for bacteriological growth were taken and sensitivity tests were carried out in all patients with fistulas and repeated later in regular intervals.

Staphylococcus aureus was cultured in 80 per cent (50/62), 68 per cent (34/50) of them were penicillin resistant but in 84 per cent (42/50) the organisms were highly lincomycin (Lincocin®) sensitive and only three patients with four osteomyelitic lesions (8 per cent) presented lincomycin resistance. Lincomycin sensitivity tests were not performed in the remaining four patients (8 per cent). Phage typing was done only in about one-third of the cases.

Thus, the lincomycin treated group comprised the 42 patients with high lincomycin sensitivity, three patients with no bacterial growth in spite of several cultures, and two patients with highly lincomycin-sensitive strains of bacillus and Gram-positive anaerobic rods respectively.

Table 4 demonstrates that more than half of the lincomycin-treated cases were given this drug for more than 6 months. The drug was usually instituted a few days before operation in doses of

Table 4 Duration of lincomycin treatment in patients with osteomyelitis after osteosynthesis

	Number	Per cent
< 3 Months	6	11
3–6 "	15	32
6–12 "	22	41
> 12 "	4	6

500 mg four times a day and continued until about 4–5 weeks after healing and then reduced to 500 mg two or three times a day.

The only side effect was a mild transient looseness of the stools which occurred in 3 patients and did not necessitate discontinuation of the drug. The three patients with lincomycin resistance and the four who were not given lincomycin sensitivity tests, and four others

while the remaining four received no antibiotic therapy.

The surgical procedures used in our 62 patients are summarized in Table 5. In 30 operations with stable mechanical conditions, mostly in the extremities, a closed irrigation suction technique was used with polyethylene tubes of 6–8 mm diameter, perfusing the wound with 0.4 per cent lincomycin solution. An irrigation of 1000 cc Ringer's or physiological saline solution with 60 mg (4 ml) lincomycin lasted from 4–7 days, the amount of liquid used was 1000–1400 ml per 24 hours.

The mean period of stay at the primary hospitals was 60 days and in our department 13 days, i.e., a total mean hospitalization period of 4 months.

RESULTS

The results were recorded as follows

Good – 74 per cent (46/62)

Fair – 8 per cent (5/62)

Poor – 18 per cent (11/62)

At the time of follow-up, there were no cases of pus secretion or pseudarthrosis and none of the patients were receiving any form of antibiotic therapy. The 47 patients treated with lincomycin did not complain of side effects after its withdrawal. The results were significantly better among the 33 cases with

Table 5 Operative treatment of osteomyelitis after osteosynthesis in 62 patients with 63 fractures

	Number	
debridement	50	
Hoffmann's apparatus	2	
+ bone transpl	1	53
resection/removal of metal implant	3	
Osteosynthesis	2	5
osteosynthesis		2
removal of metal implant	19	
Hoffmann's apparatus	1	20
amputation	12	
bone transplantation	6	
+ cross-leg/Hoffmann's app	1	19
arthrosis operation /bone transpl	10	
Osteosynthesis	2	12
dist. op/inlay of elec. stimulator		1
amputation		8
dist. procedure (split skin graft, cross-leg with delay skin tube)		22
		142

Table 6 Working capacity at follow-up of 62* patients with osteomyelitis after osteosynthesis

	Number	Per cent
full working capacity	41	66
person (normal daily activity)	5	8
partial pension owing to osteomyelitis alone	9	15
partial pension owing to osteomyelitis and other diseases	3	5
partial pension prior to injury	3	5
* 1 patient had died		

cultures of *staphylococcus aureus* (31/61 fair/6 poor) as compared with 9 cases of bacitracin resistant mixed infections (2/1 fair/6 poor).

However, amputations had to be performed in eight cases (13 per cent), three poorly healed infections with hip, shoulder and ankle damage respectively needed secondary osteotomies and two angular deformities needed corrective osteotomies. The osteomyelitis healed without removal of metal implants in only four patients.

Orthopaedic fractures occurred in six (10 per cent) and two of them belonged to the amputation group. In the initial osteomyelitis three open transverse tibial shaft fractures and two closed transverse femoral shaft

fractures were fixed with plates and one open transverse humeral shaft fracture was nailed by one Rushpin.

Before and after the treatment at our hospital the mean sedimentation rate was 32 mm/hour (range 25-115) and 9 mm/hour (range 2-40), respectively.

Table 6 shows the working capacity at the follow-up examination and it is pointed out that two-thirds of the patients are doing full-time work, seven of them after having been through a rehabilitation programme.

DISCUSSION

Pathophysiologically, post-traumatic or exogenous osteomyelitis is a primary local

affection characterized by avascularity (Burn 1975, Popkirov 1971, Waldvogel et al 1971). The transition to a chronic stage begins in the first days after the injury because this type of osteomyelitis represents both an ischaemic and an infectious problem. A sequestrum is frequently present initially. Table 3 shows that the symptoms of post traumatic osteomyelitis could be diagnosed within 1 month of the injury in 60 per cent of the material.

Sequestrectomies and saucerizations, eventually combined with removal of implants and renewed internal or external fixations were the chief methods of treatment used in our cases, but other methods such as bone transplantation and skin reconstruction have proved valuable in healing the infection (Table 5).

The surgical treatment is difficult, time-consuming and full of disappointments because of recurrent flare-ups, fistulas and pathological fractures. The orthopaedic surgeon should try to plan a schedule of treatment for each individual case, this may eventually mean several interventions per patient. Taking into consideration that about 100 operations were performed at the primary general surgical departments this means a mean total of four operations per patient.

An integration of radical surgery and antibiotic therapy is essential in the management of most cases of post traumatic osteomyelitis (Rowling 1970). The group of 47 patients treated with surgery and lincomycin achieved a satisfactory result in 85 per cent and the difference between the results in pure *staphylococcal* infections and in mixed ones is significant. The lincomycin sensitive organisms usually disappeared but the mixed infections continued in three patients and necessitated amputations.

The three patients with four lincomycin resistant lesions also deserve a few comments. Two patients with pure cultures of *staphylococcus aureus* showed resistance at the first test and in the subsequent 6 and 9 cultures respectively and ultimately amputation was performed. The last patient with

two osteomyelitic foci with mixed infection showed lincomycin sensitivity in the first test and subsequently several cultures show resistant *staphylococcus aureus*.

In our opinion the advantages of a clove irrigation-suction technique are that it provides mechanical rinsing of the wound, penetrates necrotic tissue not yet removed with a radical procedure and it prepares a profuse purulent focus for an immediate later acceptance of a cancellous graft.

Such a perfusion with lincomycin was used in about half the cases, and was perhaps more successful in the various infected pseudarthroses in connection with rigid transkeletal fixation. The irrigation was largely applied as described in the literature (Compere et al 1967, Dombrowski & De 1966, Michelinakis 1972, Taylor & Maude 1970, Willenegger et al 1970) but the technique must be carefully adapted to the individual case. The importance of inserting the tubes through oblique cortical burr-hole at a good distance from the focus to avoid kink and blocking of the inlet and outlet drains is emphasized. Moreover, the efficiency of the irrigation system with the overlapping tube ends must be tested with 250-500 ml of solution during and after wound closure and frequently checked during the first 24 hours.

From a therapeutic point of view it is of all of great importance to establish whether the osteomyelitic process is combined with pseudarthrosis or not. On admission, 44 per cent of the infected fractures in this material also revealed a pseudarthrosis which creates great therapeutic problems. In most cases bridging of a purulent pseudarthrosis with autologous cancellous bone grafts should be postponed until the infection has subsided. It is safer to saucerize and remove sequestra and unstable metal implants combined with irrigation and renewal of rigid internal or transkeletal fixation as a first procedure and to perform bone grafting as a secondary measure on a freshened pseudarthrotic bed a few weeks later. The analysis of this series also supports the observation made by others (Alho et al 1972, Macauland & Eklund

McNeur 1970) that it is an advantage to maintain a rigid osteosynthesis even during an aggressive form of osteomyelitis until the fracture has clinically consolidated. The tendency to heal is determined as much by the consolidation of the fracture as by the reversal and restitution of the infectious process.

In a few cases the ischaemic component of the tibial osteomyelitis with pronounced saucerization is undoubtedly so evident that skin grafting reconstructions are necessary to promote healing and prevent recurrence. It seems unsuccessful to perform split-skin grafting primarily upon saucerized cavities packed with cancellous bone. In this respect our experience corresponds with that of Burn (1975) who states that it is more profitable not to close the skin but to wait for spontaneous epithelialization or put split-skin grafts on the granulation tissue as a secondary measure.

A question which sooner or later always arises in this field of surgery concerns the magnitude of the saucerization because a distal bone excision inevitably means a distal weakness and the danger of a pathological fracture. In a given case a little more than half of the shaft might be removed to obtain an adequate blood circulation on all surfaces. Our series indicates that a pathological fracture is a complication that may lead to subsequent amputation. Autologous cancellous bone transplantation constitutes the best prophylactic measure.

The results in our series are encouraging enough: the amputation rate was 13 per cent. In the pre-antibiotic era the rate of amputation was over 50 per cent, while the rate today according to the literature varies between 2.2 and 15 per cent (Burn 1975). Of our eight amputated patients with open and two closed tibial fractures, three were primarily fixed with plates using the posteromedial approach.

The use of metal for internal fixation has led to an increased incidence of infection. Osteosynthesis provides stability and osteosynthesis material is covered by

sufficient live tissue (McNeur 1971). Hagen (1969) reported osteomyelitis among 129 non-leg and femur fractures (4.5 per cent) none (0 per cent) after osteosynthesis of corresponding fractures.

However, the increasing number of high velocity road traffic accidents with extensive soft tissue damage and comminuted tibial fragments require special consideration. The injury is already comprehensive and any additional approach to the medial surface of the tibia entails a potential risk of subsequent osteomyelitis (Bauer et al 1962; Edwards 1965).

The lateral approach to the tibia for plate osteosynthesis seems to be a better choice from an infectious as well as a biomechanical point of view. If there is extensive damage to soft tissue both pretibially and laterally, the possibility still exists of using the little known posteromedial approach to the tibia which is seldom used. Lastly, a transfixation procedure with Hoffmann's apparatus may also be a very valuable form of treatment for these fractures with severe soft tissue damage (Olerud 1973).

In conclusion, it now often seems possible to heal bone infections of this type if the surgical procedure is sufficiently radical and combined with appropriate antibiotic therapy. In addition, in certain cases plastic reconstructive methods and extraskelatal fixation are necessary to avoid disappointments in this challenging field of orthopaedic surgery.

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THE PENETRATION OF CEFAZOLIN, ERYTHROMYCIN AND METHICILLIN INTO HUMAN BONE TISSUE

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The penetration of cefazolin, erythromycin and methicillin into normal bone was studied in 20 patients undergoing surgery for fracture in the trochanteric region of the femur. The antibiotic concentrations were determined in serum, bone marrow and cancellous and cortical bone. For all three antibiotics the bone marrow concentrations were of the same order of magnitude as the serum concentrations. In the eight patients receiving erythromycin, detectable concentrations were found in all the cancellous bone specimens (ranging from 1/7 to 1/2 of the serum concentration) and in three cortical bone specimens (ranging from 1/50 to 1/5 of the serum concentration). In the six patients receiving cefazolin a detectable concentration was found in only one cancellous bone sample. In the six patients receiving methicillin, detectable concentrations were found only in the blood contaminated specimens of one cancellous and two cortical bone samples. However, by the method used the recoveries of standard solutions of methicillin in cancellous and cortical bone were about 50 per cent and 15 per cent respectively.

Key words: antibiotic, bone tissue, cefazolin, erythromycin, methicillin.

Accepted 21 v 78

Several studies of antibiotic concentrations in bone tissue have been performed, but the results are difficult to compare and often conflicting (Bravis et al 1977, Smilack et al 1976). This could be due to differences in the bone type examined (Evaskus et al 1969, Klein et al 1977), whether there are dissections made between bone marrow, cancellous and cortical bone (Hansen et al 1975), variations in the amount of blood contamination of the bone specimens, and

differences in the homogenization or extraction procedure, and the assay method used (Parsons 1976, Dornbusch et al 1977).

The present study was concerned with the measurement of cefazolin, erythromycin and methicillin concentrations in bone tissue from the distal femur of patients with fractures in the trochanteric region, using a homogenization procedure already described for antibiotics (Hansen et al 1975, Niel 1976).

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RESULTS

The concentrations of cefazolin, erythromycin and methicillin in bone marrow, cancellous and cortical bone, as well as the calculated serum values are shown in Table 1. Furthermore the dose of antibiotic and the time interval between the last dose (or the end of infusion) and the taking of bone specimens are shown.

It is seen that the bone marrow concentrations were of the same order of magnitude as the serum concentrations for all three antibiotics.

All the bone specimens from the six patients receiving cefazolin were blood contaminated, even so there was a detectable

concentration in only one cancellous bone sample (12 µg/g).

In the eight patients receiving erythromycin, the concentrations in the cancellous bone samples ranged from 0.6 to 5.5 µg/g which was 1/7 to 1/2 of the corresponding serum values. In cortical bone there were detectable concentrations in the two samples with visible blood contamination which gave 0.51 µg/g and 1.8 µg/g, but a detectable concentration of 0.18 µg/g was found in only one of the non-contaminated samples. However, by the method used the recovery of standard erythromycin solutions in cortical bone was only about 35 per cent (see material and methods).

In the six patients receiving methicillin

Table 1 The concentration of cefazolin, erythromycin and methicillin in serum (calculated) and bone tissue

Antibiotic	Pt no	Dose (g)	Time after last dose or the end of infusion (min)	Antibiotic concentrations			
				Serum (µg/ml)	Bone marrow (µg/ml)	Cancellous bone (µg/g)	Cortical bone (a) (µg/g)
Cefazolin	1	1	45	81	43	12*	ND*
	2	1	325	6.8	10	ND*	
	3	1	175	44	44	ND*	
	4	1 × 4	120	90	94	ND	
	5	1 × 3	265	31	34	ND*	
	6	1 × 3	180	27	35	ND	
Erythromycin	7	0.5	90	2.1	2.1	0.6*	ND
	8	0.6	45	7.8	5.7	2.3*	0.5*
	9	1	65	9.8	8.7	4.6	1.8*
	10	1	15	11	NT	5.5	NT
	11	1	95	7.6	6.8	1.8	ND
	12	0.9	40	NT	12	2.3	0.18
	13	1	145	11	11	3.4	ND
	14	0.6	■	7.8	NT	1.2	ND
Methicillin	15	1	75	29	6.2	NT	2.9*
	16	1	70	21	17	3.0	2.5
	17	1	75	30	22	ND	
	18	1	70	15	10	ND	
	19	1	60	37	19	ND	
	20	1	80	22	13	ND	

* Visible blood contamination. ND Not a detectable concentration. NT Not tested.

a) Measurements of the concentration in cortical bone specimens were performed only when the corresponding cancellous bone samples showed detectable concentration.

MATERIAL AND METHODS

Twenty patients, 12 females and 8 males, were studied. Their ages ranged from 48 to 92 years, with a mean of 75 years. All patients had a unilateral per- or subtrochanteric fracture of the femur, and they all underwent osteosynthesis *ad modum* Ender, an intramedullary fixation using three or more nails. (Briefly, the nails are introduced just above the medial femoral condyle and passed up the shaft, across the fracture and into the neck and caput of the femur.) None of the patients had received antimicrobial medication for at least 7 days prior to this investigation. Serum creatinine was normal in all patients.

Bone specimens were taken from the medial supracondylar region of the femur as soon as the bone was exposed for the osteosynthesis. In the first nine patients cortical bone was taken with a Lexcelles cutting nippers, whereas a curette was used for the cancellous bone. It was, however, impossible by this method to avoid visible blood contamination of the specimens. Because of this the subsequent bone specimens were taken with a cylindrical drill with an internal diameter of 10 mm, by means of which it was possible to obtain a cylinder consisting of both cancellous and cortical bone, without visible blood contamination. Immediately after the samples were taken, cancellous and cortical bone were separated and stored at -20°C until assayed. Bone marrow was obtained by aspiration through a metal cannula introduced through the biopsy hole and placed 5–10 cm proximally in the marrow canal. The marrow material was centrifuged and the supernatant (except the fat fraction) was used for the measurements.

After weighing the bone specimens were homogenized according to the method of Hansen *et al.* (1975) to a particle size of 0.3–3.2 micrometers. Cancellous bone was homogenized for 1 hour and cortical for 4 hours. Bone materials were dispersed in pooled human serum. For technical reasons serum four times the volume of the specimens was added to the cancellous bone prior to the homogenization procedure as described by Hansen *et al.* whereas serum twice the volume of the specimens was added to the cortical bone after homogenization.

All the antibiotics were given intravenously prior to surgery. Cefazolin (Kefzol[®]) was given in doses of 1 g. Erythromycin was administered as a continuous infusion of a solution containing 1 g erythromycin-lactobionate (Abbott) in 1000 ml 0.9 per cent sodium chloride. The average infusion rate was 650 mg per hour. The infusion was stopped prior to the operation, and the total amount given ranged from 500 mg to 1000 mg.

Methicillin (Lucopenin[®]) was given as a single 1 dose. The time interval from the last dose given (or the end of infusion) until the bone and marrow specimens were taken ranged from 15 to 35 minutes with a mean of 106 minutes.

Two samples of venous blood were drawn between 5–90 minutes before, and between 25–120 minutes after the bone specimens were taken. The antibiotic concentrations in serum were determined either on the same day, or if serum was stored at -20°C until assayed. The antibiotic concentration in serum at the time of bone specimens were taken was calculated according to the formula $y = y_0 e^{-kt}$ where y is the concentration at time t , y_0 is the concentration at time 0, and k is the elimination rate constant.

A strain of *Bacillus subtilis* was used as the test organism for all three antibiotics. Difco Antibiotic Medium No. 4 was used for cefazolin, methicillin and Antibiotic Medium No. 3 for erythromycin.

Standard solutions of antibiotics were prepared in pooled human serum for the following reason. When standard solutions of cefazolin and erythromycin were prepared by adding known amounts to cancellous bone followed by 1 hour homogenization, standard curves identical to the curves obtained in pooled human serum were found. However, when methicillin was added to cancellous bone and homogenized for 1 hour the recovery was only 32 to 74 per cent measured against serum standards. When the three antibiotics were added to cortical bone and homogenized for 4 hours the recovery was only 56 per cent for cefazolin, 19 to 50 per cent for erythromycin, and 4 to 30 per cent for methicillin against serum standards. It is seen that the recovery for each antibiotic varied considerably from experiment to experiment and by using these homogenates as standard solutions no accurate standard curves would be obtained.

Because of the low recovery after the 4 hour homogenization procedure measurements of antibiotic concentrations in cortical bone specimens were performed only when the corresponding cancellous bone samples showed detectable concentrations.

Minimum serum and marrow concentrations detectable were 0.5 $\mu\text{g/ml}$ for cefazolin, 0.06 $\mu\text{g/ml}$ for erythromycin and 0.3 $\mu\text{g/ml}$ for methicillin. The corresponding concentrations in cancellous bone homogenates were 2.5 $\mu\text{g/g}$, 0.3 $\mu\text{g/g}$ and 1.1 $\mu\text{g/g}$ and in cortical bone homogenates 0.15 $\mu\text{g/g}$, 0.18 $\mu\text{g/g}$ and 0.9 $\mu\text{g/g}$ respectively. (In three specimens less than the standard 200 mg bone material was available and the minimum measurable concentrations were higher.)

of erythromycin were found in bone tissue. Cefazolin and methicillin showed sufficient marrow concentrations, but detectable concentrations in bone samples were only found infrequently, which as regards cefazolin was in contrast to the high bone concentrations reported by other authors.

ACKNOWLEDGEMENT

We thank Dorthe Østergaard and Margrethe Lundberg Nielsen for skilful technical assistance.

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METHYLMETHACRYLATE HYPERSENSITIVITY IN A PATIENT WITH CEMENTED ENDOPROSTHESIS

A Case Report

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A case of methylmethacrylate monomer hypersensitivity in a 76-year-old patient with a cemented endoprosthesis is reported. The accuracy of a method for preoperative testing of a patient's sensitivity is discussed.

Key words: allergic reaction, hip arthroplasty, methylmethacrylate

Accepted 13 May 1977

After reports of several cases of sudden death during endoprosthesis fixation with methylmethacrylate cement (MMC) (Kepes et al 1972, Monteny et al 1975) as well as various cases of loosening of the prosthesis or of skin eruptions due to an allergic reaction (Houfflioux 1959, Laugier & Fousereau 1966, Ashman & Miller 1976, Oleffe & Wilmet 1972) attention has been drawn to the possible hypersensitivity of these patients to the different components, i.e., metal and MMC, introduced into the organism during operation.

Benson et al (1975), Elves et al (1975), Evans et al (1974) and Nater et al (1976) reported a high incidence of hypersensitivity to nickel, cobalt and vanadium in patients with a hip prosthesis. In the present study patients with a hip arthroplasty were investigated for sensitivity to methylmethacrylate monomer (MMM) by patch tests and a case of hypersensitivity to MMM is reported.

CASE REPORT

A 76-year-old woman underwent a left replacement. During implantation of endoprosthesis and the acrylic cement into femoral shaft the blood pressure decreased characteristically. The postoperative course was uneventful. The patient's history revealed that she had undergone a Moore arthroplasty for a transcervical fracture of the right hip 6 years previously. She wore a double dental prosthesis without trouble. Patch tests were performed 6 weeks postoperatively. The 5 per cent V patch test was negative whereas the 20 per cent MMM patch tests were strongly positive. Biopsy of the last test was interpreted as an allergic response following the main line (Achten & Oleffe 1966).

METHODS

during operation and reduced to normal

and. After the first results 20 and 40 per cent MMC (in olive oil) tests were added to the test tray.

Forty-two patients were investigated (36 men and 6 men, average age 68.9 years). All patients underwent a hip arthroplasty using MMC (McKee-Farrar and Moore). The case notes revealed earlier hip arthroplasty in nine patients, dental prostheses in 31 and both hip and dental prostheses in seven.

He patch tests were performed on the arm as the patients were lying on their back. To limit possible evaporation phenomena the tests were covered with a MMC cup or an occlusive patch (Silverpatch Van Der Bend). The tests were applied for a period of 48 hours and after 48 and 96 hours.

DISCUSSION

Hypersensitivity to methylmethacrylate has been reported to occur in dentists (Fisher 1965), patients with dental prostheses (Fisher 1965, Dechaume & Brunel 1948, Fisher et al 1970, Jedrzejewski & Lewicz Stysiak 1970), manicurists (Fisher 1965, Fisher et al 1957) and a laboratory technician (Moody 1941) but the incidence of methylmethacrylate skin sensitivity in the general population remains unknown. Nyquist (1958) noted 90 per cent allergic reactions in a student nurse population with a 5 per cent concentration dispersed in oil or paraffin. On the contrary, Nater (1976) with the same concentration in paraffin did not obtain a single positive reaction in patients with total hip replacement.

The authors agree upon the role of MMC as an allergen. After polymerization of MMC the polymer may be considered as inert. Provided the reaction of polymerization is complete and no monomer is left, patients with a cemented endoprosthesis are not allergic to MMC. Sensitivity to MMC seems to be very rare (Fisher 1965, Nater et al 1976). A certain amount of MMC is pushed into the injured blood vessels when the prosthesis and cement are packed into the femoral shaft (Fisher 1969, Pahuja et al 1974). This may produce a sensitization reaction

as the elimination of the monomer via the respiratory system is reduced (Derks & D'Hollander 1977). The negative reactions with the polymer reduced in powder confirm previous works (Oettel 1963). Our study is also in accordance with Nater's results (1976) as no positive reaction was observed with a 5 per cent concentration of MMC.

In view of the conflicting results further investigations of methylmethacrylate sensitivity are relevant. We believe a 20 per cent concentration of MMC is more adequate than a 5 per cent concentration. Chloroform is used as a solvent. As a 40 per cent concentration is usually employed to test chloroform allergy (Fisher 1975) the latter is not involved in the reaction.

ACKNOWLEDGEMENTS

This study was performed in the Orthopaedic Department of the Brugmann University Hospital (Prof de Marneffe) Brussels.

The authors would like to thank D. Roosels, Sc.D., Chemical Advisor, Laboratory Head, Occupational Diseases Fund, Brussels, for his assistance in this study.

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AMPUTATION AFTER DEVELOPMENT OF COLLATERAL CIRCULATION

Arteriographic Study in Rabbits

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The vascular changes in the amputation stump after amputation on an extremity which is vascularized by collaterals were studied by arteriography in adult rabbits.

Amputation on the crus immediately after ligation of the femoral artery caused a retardation in the development of collaterals and a protracted vasoconstriction in the amputation stump. Osseous plugging of the medullary cavity in the amputation stump counteracted the vasoconstriction and the development of collaterals was improved. When amputation on the crus was performed 3-6 days after ligation of the femoral artery immediate function of the collaterals and a rapid dilatation of the arteries in the below knee amputation stump were seen and 3-4 weeks postoperatively arteriovenous shunts developed in the stump. Amputation 7-10 weeks after ligation of the artery involved a more pronounced shunt development in the amputation stump.

After amputation on the femur only slight differences were observed in the development of collaterals and the vascularization in the amputation stump compared with findings after amputation on the crus.

Key words: amputation, arteriovenous shunt, collateral circulation, in tracardial arteriography, vascular spasm.

Accepted 23 v 78

be vascular changes occurring after amputation may influence the healing process in the amputation stump, especially if the amputation is performed on an extremity with reduced arterial supply. In earlier experimental investigations arteriography has shown that amputation initially induces vasospasm (Enkson & Olerud 1966) and secondarily causes arteriovenous shunts to develop in the stump (Hansen Leth & Karle 1978). When amputation is performed on an extremity supplied by collaterals, the degree of occlusion of the femoral artery, the muscle blood flow to the stump will depend

on the time interval between the ligation and the amputation (Hansen Leth 1978).

The aim of this investigation was to elucidate the arteriographic changes in the amputation stump after amputation on extremities supplied by collaterals. Arteriography was performed after intracardial injection of contrast medium in the earlier investigation (Hansen Leth & Karle 1978).

MATERIALS AND METHODS

The studies were performed on 24 adult rabbits weighing 3-4 kg. Eighteen rabbits had been

Table 1 Examples of repeated arteriographic investigations on the same rabbit
Operations Time of arteriography

	Rabbit N 62		Rabbit N 70	
Ligature of the femoral artery	Preoperative 1 hour after ligature 1 week after ligature			
Ligature of the femoral artery	10 weeks	+ 1 hour	1 week	+ 1 day
+ amp on crus	— —	+ 2 weeks	— —	+ 1 week
	— —	+ 4 —	— —	+ 3 —
	— —	+ 10 —	— —	+ 5 —
	— —	+ 13 —		
Ligature of the femoral artery			10 weeks	+ 1 hour
+ amp on femur			— —	+ 1 week
			— —	+ 6 weeks
			— —	+ 8 —

proximal part of the left femoral artery, and the amputation stumps were in all cases closed by myoplasty. In nine rabbits amputation proximally on the left crus was performed immediately after the ligature - in three of these myoplasty was combined with osseous plugging of the marrow cavity. In five animals amputation on the crus was carried out 3-6 days and in a further five animals 7-10 weeks after the ligature. Finally, in two animals previously amputated on the crus - amputation on the femur was performed 1 week and 10 weeks after the ligature. Two animals were not amputated at all.

All the operations were performed under Nembutal anaesthesia. The femoral artery was double-ligated with silk and the stump was closed with silk knots in the muscles and nylon in the skin. The marrow cavity was plugged with cortex obtained from the removed bone.

Arteriography was carried out as previously described (Hansen-Leth & Karle 1978). Under Nembutal anaesthesia a lumbar needle (90 x 0.9 mm) was inserted through the skin at the tip of the xiphoid process and thrust into the heart. The needle was kept open with heparin-saline solution and a bolus of 6 cm³ 76 per cent Urographin was injected manually for a period of 15 seconds. Six pictures were taken immediately thereafter (1 exposure every 2 seconds). This procedure clearly portrayed the arterial and venous phase and the transit-time through the arteries and the appearance of the venous phase could be determined.

The degree of change in arterial diameter was measured on subtraction films at corresponding levels by the use of a magnifying glass and a scale

permitting readings with a precision of 0.1 mm. The magnification factor was so small that it could be ignored (measured with a lead strip ruler placed across the pelvic area of the rabbit).

A total of 57 arteriographs were performed, 7 preoperative, seven after arterial ligature and after amputation from 1 hour to 4 months postoperatively. Two animals were arteriographed 8 times (Table 1) one 4 times, five 3 times, and twice and eight once.

RESULTS

When arteriography was performed immediately after ligature of the femoral artery, function of the collaterals from the circumflex femoral arteries and contrast filling of the distal part of the femoral artery were seen but no filling of the crural vessels. From 1-10 weeks after ligature of the femoral artery arteriography showed a moderate increase in the prominence of the collaterals and only a slight amount of contrast in the crural arteries (Figure 1).

If amputation on the crus was performed immediately after the arterial occlusion only a few collaterals were seen in the amputated limb in the first 4 weeks after the operation and the contrast filling in the stump vessels was minimal up to 6 weeks (Figure 2). When 6 weeks had passed a dilatation of the



Figure 1 (a) Ten weeks after ligation of the left femoral artery. Note the moderately prominent collaterals and almost no contrast filling of the distal arteries. (b) Postmortem angiography performed on the same rabbit through a catheter placed in the aorta. Rabbit N69.



Figure 3 Two weeks after simultaneous ligation of the femoral artery and amputation on the crus combined with plugging of the medullary cavity (N55).

supplying arteries and slight filling of the veins was observed (Table 2).

However if amputation was combined with plugging of the medullary cavity dilatation of the collaterals and the arteries in the stump was seen 1 week postoperatively (Figure 3).

After a time interval of from 3 to 6 days between ligation of the artery and amputation, arteriography showed an immediate contrast filling of the collaterals; dilatation of the arteries in the stump was seen 2 days later (Figures 4, 5). Four weeks postoperatively there was filling of the superficial and deep veins in the stump and the superficial veins in the contralateral extremity (Figure 3).



Figure 2 Ten weeks after ligation of the femoral artery and amputation on the crus performed simultaneously (N44).

In experiments with 7 to 10 weeks interval between ligation and amputation arteriography immediately after amputation showed little contrast filling of the collaterals and the vessels in the stump (Figure 6). Two weeks later more collaterals were seen (Figure 7) and there was simultaneous vein filling on both sides.

Table 2 illustrates that the flow rate in the arteries was almost constant (4–6 seconds) and independent of the time interval between artery ligation and amputation, whereas vein filling increased 2–3 weeks postoperatively and was most noticeable when a long time interval (7–10 weeks) was introduced between artery occlusion and amputation.

Contrast filling of the veins occurred simultaneously on both sides but on the contralateral extremity only the superficial veins were seen, and they disappeared when a tourniquet was placed on the distal part of



Figure 4 (a) Five days after ligation of the femoral artery. (b) One hour after subsequent amputation. (c) Two days after the amputation (N44).

Table 2 Transit time Rate of contrast filling in the vessels in the operated leg (One sign means a single picture = 2 seconds)

TRANSIT-TIME

OPERATION	1 HOUR	1/2 WEEK	1 WEEK	2-3 WEEKS	4-5 WEEKS	6-10 WEEKS	>10 WEEKS
LIGATURA ART FEMORALIS	xx	xxx	xxx xx	xxx		xx	xxx
SIMULTANEOUS LIG AND AMP CRURIS	xx	xx xx	xx	xx xxxx	xx	xx △△△△ xx ○○○	xx △ xx △△
SIMULTANEOUS LIG AND AMP • PLUGGING		xx △△△	xx △△	xx ○○ xx △△△	xxxx		
INTERVAL 3-6 DAYS	xxx xx	xxx	xx △△ xxxx	xx △△ xx △△△△	xx ○○○ xx ○○○○	xx △△△ xx ○○○	xxx ○○○ xx ○○○○ xx △△△
INTERVAL 7-10 WEEKS	xxx	xxxx		xx △△△ xxx ○○○ xxx ○○○	xxx ●●● xx ●●●●	xx ●●●●●	xx ○○○ xxx △△
LIG AND AMP FEMORIS	xxx		xx	x △△	xx	xx	

- x ARTERY OCCURRENCE
 △ VEIN SLIGHT OCCURRENCE
 ○ VEIN MODERATE OCCURRENCE
 ● VEIN MARKED OCCURRENCE

the crus, indicating that the vein filling was caused by arteriovenous shunts distally in the extremity. In the amputated extremity contrast filling of the superficial as well as the deep veins was observed, the superficial veins were especially noticeable after a long time interval between artery occlusion and amputation.

The dilatation of the supplying arteries is illustrated by the diameter of the aorta (Figure 8). The degree of dilatation with 3-6 days interval between artery occlusion and amputation was greater than after 7-10

weeks interval, and remained unchanged the investigation period, while the diameter of the aorta increased after the longer interval.

The secondary dilatation of the supplying arteries and the increased occurrence of superficial veins in the stump, especially after a long time interval between artery occlusion and amputation, could be explained by formation of arteriovenous shunts in the amputation stump.

If amputation on the femur was performed 1 and 10 weeks after artery occlusion



Figure 5 Amputation on the crus and later on the femur performed on the same rabbit (a) Three days after ligation and 1 hour after amputation (b) Three days after ligation and 5 weeks after amputation (c) Ten weeks after ligation and 1 hour after amputation on the femur (d) 10 days later (N_{10})

contrast filling of the distal part of the femoral artery was seen, the circumflex arteries were dilated but the collaterals in the stump were only slightly so and no vein filling occurred (Figure 5). However dilatation of the arteries and rapid filling of the veins were seen in the contralateral extremity.

DISCUSSION

Using intracardial arteriography it is possible to perform repeated investigations on the same animal and in this way to follow the development of collaterals after ligation of the femoral artery and the vascular changes following subsequent amputation. This study has demonstrated immediate

function of collaterals after ligation of the femoral artery. Similarly Schoop & Jahn (1961) showed immediate contrast filling of preexisting "primary" collaterals after ligation of the femoral artery on dogs while "secondary" collaterals developed in the course of the following weeks. In clinical investigations Shepherd (1950) and Dornhorst & Sharpey Schafer (1951) showed that the resistance in the collateral vessels diminished already 1 minute after acute arterial occlusion.

In the present study there was no contrast filling of the crural arteries before 1 week after the occlusion despite the development of collaterals. This is in accordance with the findings of Barnes & Trueta (1942) and Jaya (1958) who found that ligation of the femoral



Figure 6 (a) Seven weeks after ligation (b) Amputation performed at this time and the arteriography 1 week later (c) Three days later (N_{21})



Figure 7 The amputation was performed 10 weeks after ligation and the arteriography, 4 weeks later (N_{11})

artery induced a vasospasm of the peripheral arteries. Measurement of the muscle blood flow (Hansen-Leth 1978) has shown that after ligation of the femoral artery there is an immediate reduction in the blood flow to the crus.

In this study, amputation performed immediately after arterial occlusion counteracted the function of collaterals and induced a protracted vasoconstriction in the peripheral

arteries in the amputated extremity. Measurement of the blood flow in muscles (Hansen-Leth 1978) has shown that the flow in the stump is decreased during the first week after simultaneous ligation of the femoral artery and amputation on the crus. This is in contrast to crus amputation on rabbits with intact circulation where an increase in blood flow was 1 day after operation (Hansen-Leth 1976).

When amputation is done on an extremity with intact circulation an initial vasospasm will always be the result (Erikson & O 1966, Hansen-Leth & Karik 1978). However, if the amputation is performed 3–6 days after ligation of the femoral artery, an immediate dilatation of the supplying arteries and filling of the collaterals to the stump are seen. In accordance with this, determination of muscle blood flow (Hansen-Leth 1978) has shown an immediate increase in the blood flow to the stump, when amputation on the crus is performed 3 days after ligation of the femoral artery. The reason why amputation on an extremity supplied by collaterals does not provoke an initial vasospasm is not clear.

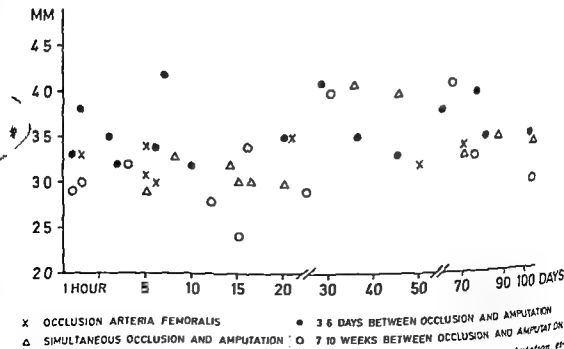


Figure 8 The diameter of the aorta. A secondary dilatation is observed 3–4 weeks after amputation especially after a long interval between occlusion and amputation

Erikson & Olerud (1966) suggested that the vasospasm after amputation could be caused by an increased sympathetic tone. From clinical investigations it is known that collaterals have a low sympathetic tone (Nelsen et al 1973). A decreased sensitivity to the sympathetic impulses could be the cause of the immediate function of collaterals after amputation.

After an extended time interval between arterial occlusion and amputation a similar natural vasodilatation and collateral function was not seen. But secondary arterial dilatation was observed after 3-4 weeks simultaneously with the occurrence of collateral filling of the superficial veins. This might be due to the development of arteriovenous shunts in the stump, and these findings can explain the diminished muscle blood flow in the amputation stump seen when amputation was performed 10 weeks after arterial occlusion (Hansen-Leth 1978).

The occurrence of superficial veins can be due to arteriovenous shunts, whereas the contrast filling of deep veins means an improvement in the venous return from the stump (Loon 1960). In a previous investigation (Hansen Leth & Karle 1978) the deep veins from the stump were only seen when amputation was combined with osseous plugging of the medullary cavity. Similarly, the present investigation has shown that plugging of the medullary cavity improved the vascularization in the stump. In accordance with this, determination of muscle blood flow (Hansen-Leth 1976) has shown that plugging of the marrow cavity induces a more rapid and greater blood flow in the stump.

Following amputation on the femur only a slight filling via the collaterals to the femoral stump was seen and there was no refilling of the femoral artery. After amputation on the tibia the femoral artery must be considered as an end artery, which is obliterated at the level where it joins with the circumflex tibial arteries. The vascularization of the amputation stump takes place only through

small terminal branches, the fall in blood pressure through these is marked (Learmonth 1950) and the capillary blood flow in the stump will be diminished. In accordance with this, determination of muscle blood flow has shown no increase in the flow in the stump after amputation on the femur (Hansen-Leth 1977).

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PNEUMATIC TOURNIQUET AND LIMB BLOOD FLOW

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The response of limb circulation to tourniquet ischaemia in the hind limb of the rabbit was studied. Muscle blood flow was evaluated by means of a local isotope technique using Xe^{133} as the tracer and the changes occurring after tourniquet ischaemia of 60-180 minutes duration were investigated. The results obtained suggest that even when the tourniquet time is extended to 3 hours, no blood flow occurs in the limb distal to the tourniquet when the cuff is inflated to 300 mmHg. In all animals a hyperaemic reaction was noticed after releasing the tourniquet and a peak reactive hyperaemia was registered 1 minute after the return of circulation. The magnitude of the reactive hyperaemia was independent of the length of tourniquet time. The hyperaemia was regularly of short duration and peak flow values were reached in 1 minute with the flow returning to normal or subnormal values after 5 minutes. Phlebography studies in 12 rabbits after 120-240 minute tourniquet blockade showed only one thrombosis in a deep popliteal vein after the 240-minute tourniquet time.

Key words: pneumatic tourniquet, limb blood flow, ischaemia, thrombosis

Accepted 20 iv 78

Pneumatic tourniquet is a commonly used technique for the exsanguination of a limb and obtaining a bloodless field for surgery of the extremities (Esmarch 1873, Cushing 1904). Some authors suggest that despite correct application of the tourniquet blood may flow into the distal part of the limb by the way of the medullary canal (Spira et al 1965, Furlow 1971), the amount varying from 1 to 26 per cent of the flow to the unoperated limb. Klennerman & Crawley (1977) reported, however, in an experimental study, that the circulation was reduced to less than 1 per cent of that of the control limb.

Reddening of the skin of the limb after removal of the tourniquet as a sign of reactive hyperaemia was observed by Bier already in 1897. Even a short occlusion of the arterial blood flow of less than 5 minutes produces reactive hyperaemia (Myhre 1975). However, there is little accurate data on the blood flow

to the limb after releasing the tourniquet. Several methods have been used to study reactive hyperaemia, venous occlusion plethysmography being one of the most common. However, this technique may impede the arterial blood flow and, furthermore, the measurement must be made at intervals (Dahn 1965). Estimation of venous outflow by drop recording technique and electromagnetic flowmetry have been successfully used to measure rapid changes in blood flow after brief arterial occlusion (Thulesius 1962, Myhre 1975). Recently, the local isotope clearance technique using Xe^{133} as the tracer has proved to be a convenient method to evaluate muscle blood flow (Landbjerg 1966, Siggaard-Andersen & Bonde-Petersen 1967). In these experiments the circulatory occlusion was extended to 60 minutes. A reactive hyperaemia was always noted after the return of circulation.

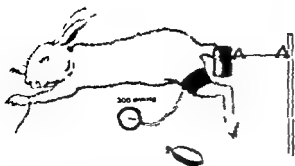


Figure 1 Schematic illustration of the model used in the experiments. The scintillation detector for the ^{137}Xe wash out registration was placed 5 cm above the limb.

Postoperative venous thrombosis has been considered as a rare complication after pneumatic tourniquet (Geens *et al.* 1969; Potter *et al.* 1972). However, other authors have reported, in phlebographic studies that the incidence of venous thrombosis after pneumatic tourniquet varies from 10 to 60 per cent (Cohen *et al.* 1973; Kroese & Suris 1976). Evidence has been presented that the thrombosis appears already during the first postoperative hour (Flanc *et al.* 1968; Negus *et al.* 1968).

The purpose of this study was to clarify the circulatory situation in the limb during the use of the pneumatic tourniquet to evaluate the blood flow after releasing the tourniquet and to find out if postoperative thrombosis appears as a complication.

MATERIAL AND METHODS

Thirty-one rabbits of both sexes, weight 2.7–3.4 kg, were used in this study. Anaesthesia was induced with intravenous sodium pentobarbitone and maintained by continuous ether inhalation.

The left hind limb was exsanguinated with an Esmarch rubber bandage and tourniquet blockade was applied by means of a 6 cm broad Riva-Rocci type cuff around the upper part of the leg the cuff being inflated to 300 mmHg (Figure 1). The response of different periods of tourniquet blockade on the extremity blood flow was investigated. Six rabbits were subjected to 60 minutes of tourniquet ischaemia, another six to 120 minutes, the remaining six being subjected to 180 minutes of tourniquet ischaemia.

The hind limb blood flow was measured by the ^{137}Xe wash out technique. Into the middle part of the anterior tibialis muscle 0.2 ml of a solution of ^{137}Xe was injected in sterile isotonic saline (mCi/ml Rotop[®], Isocommerz GmbH, Ref. Buch DDR) with a thin needle (No. 16 OD 1 mm). The injection was performed for 10 seconds, the needle being withdrawn 20 seconds after finishing the injection. The disappearance rate of the isotope from the limb was followed by means of a scintillation detector with a thallium activated NaI-crystal which was placed 5 cm above the limb. The scintillation detector was coupled to a Wallac[®] ratemeter (Wallac Ltd, Turku, Finland). The output from the ratemeter was recorded on a logarithmic Servogor[®] chart recorder (C. Electro GmbH, Vienna, Austria). On the evaluation of diffusion equilibrium of ^{137}Xe between tissue and blood, calculation of the muscle blood flow was made according to the Fick principle (Lindberg 1966).

Phlebography of the hind leg after pneumatic tourniquet was performed on a further 12 rabbits. Four rabbits had a 120-minute tourniquet ischaemia and in four rabbits the duration of blockade was 180 and 240 minutes, respectively. Radiographic examination was performed 30 minutes after the release of the tourniquet. After the injection of the contrast medium, the skin on the hind leg was incised and a catheter was inserted into the distal part of the great saphenous vein. An angiogram was taken also with phlebography to visualize the deep veins of the limb.

In one rabbit an angiogram of the common femoral artery and its distal ramifications was performed. After laparotomy a catheter was introduced through the left renal artery into the aorta. An angiogram was taken during the tourniquet occlusion and 30 minutes after the release of the tourniquet.

RESULTS

The average of 18 determinations of normal blood flow baseline in the hind limb was 24 ± 8.1 ml/min/100 g muscle (mean \pm s.e.m.).

During the tourniquet blockade no decrease of ^{137}Xe activity could be demonstrated, indicating that no wash out occurred. This observation was made in all the rabbits under investigation and the tourniquet blockade did not affect the results.

When the tourniquet blockade was re-

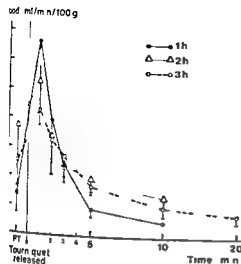


Fig. 2 Reactive hyperaemia registered after releasing the tourniquet. Note the peak of the flow 1 minute after onset of the circulation. The magnitude of the hyperaemia was not significantly dependent on the tourniquet time. In 5 to 10 minutes the flow had turned to normal or subnormal values. PT=pretourniquet.

60 minutes, the Xe^{133} wash out increased 1 minute after return of the circulation to 68.8 ± 12.4 ml/min/100 g ($P < 0.05$). After this, the wash out decreased sharply. Five minutes after releasing the blockade the flow out was lower than the normal baseline value (42 ml/min/100 g) (Figure 2).

In the 120-minute group the Xe^{133} wash out increased 1 minute after tourniquet release to 52.1 ± 8.5 ml/min/100 g. Five minutes after the release the value for wash out was 19.2 ± 2.1 ml/min/100 g.

In the 180-minute group 1 minute after release of the tourniquet blockade the wash out increased to 42.1 ± 8.7 ml/min/100 g and declined 5 minutes after the release to 5.5 ± 2.0 ml/min/100g.

Phlebography revealed one venous thrombosis in a deep popliteal vein after 4 hours tourniquet blockade (Figure 3b). In all the animals phlebography revealed a patent blood flow. In all rabbits the phlebography was technically successful, but thrombosis could not be demonstrated (Figure 3a).

In the angiogram a clear occlusion of the arterial blood flow was seen just above the inflated tourniquet cuff.

The control angiogram 30 minutes after the onset of circulation showed a normal angiogram in the tourniquet limb.

DISCUSSION

In 1949, Kety suggested that tissue blood flow could be measured by means of the disappearance of locally injected radioactive isotopes. Applying this principle, a radioactive isotope of the inert gas Xenon (Xe^{133}) has been used for experimental and clinical measurements (Lassen et al 1964, Lindbjerg 1966). This isotope has proved to have theoretical advantages over other isotope clearance methods (Lassen et al 1964).

The results obtained in the present investigation, using the Xe^{133} clearance method, suggest that even when the tourniquet time is extended to 3 hours, no blood flow occurs in the limb distal to the tourniquet cuff. This result correlates with those obtained by Klenerman & Crawley (1977). They reported a blood flow to the occluded limb of less than 1 per cent, when compared with the control limb. Their study was performed using the Na^{22} clearance method. It seems obvious that during these experimental conditions the circulation via the medullary canal is almost totally occluded and that the limb is virtually isolated from the circulation.

Hyperaemia following brief arterial occlusion has been recognized previously (Thulesius 1962, Lindbjerg 1966, Siggaard-Andersen & Bonde-Petersen 1967, Myhre 1975). However, tourniquet ischaemia is in

the present work the peak of reactive hyperaemia was in all animals registered 1 minute after releasing the tourniquet blockade. Lindbjerg (1966)



Figure 3 (a) Normal phlebography
(b) Thrombosis in a deep popliteal vein following 4 hours of tourniquet occlusion

reports in human experiments that up to a period of 5 minutes of occlusion the amount of hyperaemia increased in accordance with the duration of the ischaemia but that further prolongation of the ischaemia did not cause a further increase in hyperaemia. In Lindberg's work the maximal blood flow in the human tibialis anterior muscle was measured after 5 minutes ischaemia combined with simultaneous exercise and the peak flow of 70.8 ml/min/100 g was often maintained for more than 1 minute. In our study the maximal peak flow was registered after 60 minutes of tourniquet ischaemia and was comparable with the maximal muscle blood flow reported by Lindberg.

Shepherd (1950) and Hillestad (1963) have reported a peak blood flow of 40–50 ml/min/100 g in human calf muscles after brief strenuous exercise. These values

resemble the flow in the rabbit tibialis anterior muscle during hyperaemia following release after 120 and 180 minutes of tourniquet blockade. Thulesius (1962) suggests that blockade of the extremity blood flow has effect on the limb circulation comparable with strenuous exercise since both result in a considerable reduction of collateral resistance.

Several mechanisms have been proposed for the reactive hyperaemia such as accumulation of vasodilator substance (Lewis & Grant 1925) and reduced vascular tone due to a fall in transmural pressure distal to the occlusion (Bayliss 1902, Folkow 1964). Local oxygen deficiency has also been held responsible for reactive hyperaemia (Crawford et al. 1959). Myhre (1975) suggests that the metabolites which are accumulated during circulatory arrest enter circulation and maintain increased blood flow at least after

of prolonged occlusions. The cause of seems to be complex and can be attributed to the influence of a single

only
The blood flow in the tibialis anterior 5-10 minutes after release of the is lower than the pretourniquet value, but still within the range of values obtained under normal conditions 1950, Hillestad 1963, Lindbyerg

mental phlebographic studies to the incidence of thrombosis after ischaemia have not previously performed. Our results with only one is in 12 rabbits do not justify conclusions of clinical consequences, but suggest, however, that further experimental work should be done in this field.

On the basis of the present investigation, the results may be summarized as follows:
A pneumatic tourniquet inflated to 300 mmHg caused a total blockade of the circulation in a hind limb of a rabbit.
The magnitude of reactive hyperaemia after releasing the tourniquet did not significantly depend on the tourniquet time.
Blood flow peak values were reached 1 minute after the return of circulation, with re-establishment of normal or subnormal values during within 5-10 minutes, and postoperative venous thrombosis was found in only one animal after 240 minutes of tourniquet time.

KNOWLEDGEMENT

This work was supported by Emil Aaltonen Foundation, Pehr Oscar Klingendahl Foundation, Paulo Foundation. The authors wish to thank Erneli Lautenschlager for skilful assistance.

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OSTEOSARCOMA

A Multifactorial Clinical and Histopathological Study with Special Regard to Therapy and Survival

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A multifactorial analysis was performed on all 153 unequivocal cases of genuine osteosarcoma recorded in the Swedish Cancer Registry for the years 1958 through 1968. Cases of so-called parosteal osteosarcoma, soft-tissue osteosarcoma and osteosarcoma secondary to Paget's disease of bone were not included. The osteosarcomas were subclassified as follows: osteoblastic (69 per cent), chondroblastic (19 per cent) and fibroblastic (12 per cent). The overall 5-year survival rate was 22 per cent, 55 per cent for those who had undergone amputation above the joint proximal to the involved skeletal part, 22 per cent for those amputated on the involved skeletal part, 11 per cent for those treated with local extirpation of the tumor, and 1 per cent in cases in which the lesion was not radically removed. Tumors of the femur, humerus and scapula were as malignant as axial tumors. The former carried a 5-year survival rate of 13 per cent, regardless of whether the patients had been treated with exarticulation or amputation on the involved skeletal part. Patients with axial tumors showed a 5-year survival rate of 15 per cent. These survival data suggest that proximal amputation alone might suffice for lesions situated distally to the knee and elbow joints, while tumors in the humerus and femur should be treated with amputation combined with multicystostatic treatment or immunotherapy and axial tumors with local resection and multicystostatic or immunologic treatment.

Key words: osteosarcoma, therapy, histopathological study.

Accepted 24 v 78

Despite several reports in the medical literature of large series of genuine osteosarcoma, there is still some controversy as to the overall prognosis. In earlier reports, the estimated 5-year survival rate ranged from about 5 to over 30 per cent (Simmons 1939, Jaffe & Selin 1951), while in later series it ranges from 10 to 20 per cent (McKenna et al 1964, Dahlin & Coventry 1967). However,

the patient populations have been influenced by selection to a varying degree (McKenna et al 1964). The results might also have been influenced by improvements in diagnostic and treatment efficiency over the years.

The present investigation represents a combined clinical and histopathological analysis of osteosarcomas collected from those recorded in the Swedish Cancer Registry during the 11-year period from 1958 through 1968. The overall 5-year survival rate was determined, and also the survival in

This work was supported by grants from the Swedish Cancer Society Nos. 711 B75-03XA and 711 B76-04XB.

relation to various factors such as tumor site and kind of treatment. Primary attention was thus paid to factors which have been considered to influence the survival rate, such as histopathological type of tumor, site and size of tumor, rapidity of tumor growth and soft-tissue involvement, diagnostic measures, presence or absence of fracture, age and sex, and mode of therapy. This information may provide a basis for the indications for primary ablative surgery, either alone or in combination with adjunctive chemotherapy or immunotherapy, and also for evaluation of the results which may be achieved with new therapies for osteosarcoma, e.g. chemotherapeutics such as methotrexate or adriamycin (Editorial 1974, Cortes et al 1974, Pratt et al 1974, Sutow et al 1974, Campbell et al 1975), immunotherapeutics such as intravenous transfer of sensitized lymphocytes (Southam et al 1973, Editorial 1974, Neff & Enneking 1975) or interferon administration (Nilsson et al 1975).

MATERIAL AND METHODS

Since 1958 all cases of clearly malignant and possibly malignant tumors diagnosed in Sweden have been reported to the Cancer Registry by a very efficient system (Larsson 1971) of double reporting throughout the country from clinicians on one hand and pathologists and/or cytologists on the other hand. The reliability of the data was discussed in a report from the Swedish National Board of Health and Welfare 1974. Two hundred and forty-two patients were reported with a diagnosis of osteosarcoma during the years 1958 through 1968.

The histopathological re-examination was carried out by one of the authors (L.B.). The original slides were re-examined and new sections were prepared and stained with hematoxylin and eosin, van Gieson's stain, periodic acid-Schiff, phosphotungstic acid hematoxylin and Laidlaw's silver impregnation. Only those cases were accepted for further study in which we could prove a definite diagnosis of genuine osteosarcoma and in which complete clinical records and biopsy material were available to allow a multifactorial analysis. Cases were thus excluded in which the diagnosis of osteosarcoma had been made primarily but could not be finally proved because

of a lack of adequate histopathological material for thorough re-examination. This means that the number of patients accepted for the present analysis was smaller than the total number of recorded cases used in preceding incidence and geographical studies (Larsson & Lorentzon 1974a and b). The present series of unequivocal osteosarcoma cases thus had to be selected to enable a complete and representative analysis as possible, without limitation of the significance of the study (Lockshin & Higgins 1968).

The possible influence of various factors, such as tumor localization and type of treatment, upon the prognosis, was subjected to statistical analysis using a chi square test. When testing the possible simultaneous influence upon the prognosis of various factors such as the type of diagnostic procedure used, a multiple regression analysis was performed (Angsmark 1969, Cramer 1954). All hypotheses were tested at the 1 per cent level of significance.

RESULTS

Histopathological study

The histopathological diagnosis was osteosarcoma in all 242 cases recorded in the Cancer Registry but owing to the described criteria for our re-examination the present series consisted of only 153 proven genuine osteosarcomas. A total of 23 cases represented either parosteal or extraosseous osteosarcomas or were secondary to Paget's disease of bone. These cases were not included. Thirty cases could not be fully proven to represent genuine osteosarcoma from the available material, and a few cases with unrelated malignancies had wrongly been registered as osteosarcoma. These cases had lesions with central locations, predominantly. In 26 cases sufficient specimens and clinical records could not be obtained for a complete analysis, and six cases were excluded because their initial symptoms appeared the year before the time period covered by our study.

Histopathologically the genuine osteosarcomas were subclassified as predominantly osteoblastic in 69 per cent of the cases, as chondroblastic in 19 per cent and as

OSTEOSARCOMA
DISTRIBUTION ACCORDING TO AGE

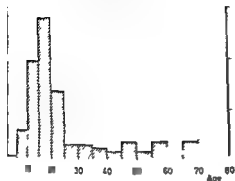


Fig. 1 Distribution of primary osteosarcoma according to age

roblastic in 12 per cent. This subclassification was found to have no prognostic value, and did assessment of the degree of malignancy according to Broder's grading (Jaffe and Price 1961) have any prognostic significance.

Age and sex

The age distribution of the genuine osteosarcomas is shown in Figure 1. One peak was obtained for the adolescent ages, two-thirds of the neoplasms occurring in persons below 30 years of age. An even distribution of the tumors was found for the adult ages. A similar age distribution was found for males and females, apart from the fact that the peak incidence occurred at a mean age of 12 years in girls and 16 years in boys, as previously reported (Larsson & Lorentzon 1974b). The adolescent incidence peak was caused by tumors localized to the long bones of the upper limbs. The genuine osteosarcomas showed a predilection for males, giving the following ratios for males to females for all ages together 1.47 to 1, in the ages below twenty-three 1.72 to 1 and in the ages above twenty-three 1.11 to 1. Age was found not to influence the prognosis in the present series. Females had a slightly better prognosis than males, the 5-year-survival rates were 23 and 31 per cent, respectively.

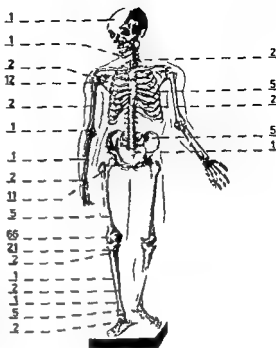


Figure 2 Skeletal distribution of primary osteosarcoma

Tumor location, and clinical and roentgenological findings

The skeletal distribution of the genuine osteosarcomas is shown in Figure 2. Forty-three per cent affected the lower portion of the femur, 14 per cent the upper part of the tibia, and 7 per cent each the upper metaphyseal region of the femur and humerus. No patient initially had more than one tumor.

Twenty-four per cent of the neoplasms had a peripheral localization, i.e. distal to the knee and elbow joints (site 1), 65 per cent were located within the femur, humerus and scapula (site 2), and 11 per cent within the pelvis, spine, sacrum, ribs, mandibula and skull (site 3).

The most frequent symptom on admission was local pain noted in 91 per cent of the patients. Local swelling was present in 81 per cent, limitation of motion of the adjacent joint in 45 per cent, pathological fracture in 14 per cent, a general feeling of sickness in 10

per cent, and neurological symptoms in 7 per cent of the patients.

The most characteristic roentgenological appearance of the lesions was an expanded, osteolytic destruction of the affected bone, with areas of calcification often with visible bony structures, and periosteal new bone formation. The majority of the cases presented with advanced lesions showing destruction of cortical bone and a relatively high frequency of pathological fractures (see above). Periosteal bone formation with spiculae and Codman's triangles was a prominent feature. The neoplasms affected roentgenologically the metaphysis of a long bone in 61 per cent of the cases, the diaphysis in 7 per cent, the metaphyseal-diaphyseal border in 21 per cent, and a flat bone in 11 per cent of the patients.

Gross appearance

Some of the tumors were soft with areas of necrosis and cyst formation, while others were firm with chondromatous or ossified areas and central sclerosis.

The tumor size was estimated on roentgenograms and in some cases also on gross examination of the removed specimen. Tumors larger than 10 cm in diameter were found in 44 per cent of the patients, tumors 5-10 cm in diameter were also found in 44

per cent, tumors 2-5 cm in 11 per cent and tumors smaller than 2 cm in 1 per cent of the cases. The peripheral lesions, i.e., those situated distally to the knee and elbow joint (site 1) were somewhat smaller (Table 1) than those in the femur, humerus and scapula (site 2) and the axial ones (site 3).

Soft-tissue involvement and joint penetration was determined roentgenographically after surgery, and at examination of the removed specimen. Involvement of the surrounding soft tissues by the tumor had occurred in 12 per cent of the cases and penetration into the adjacent joint cavity in 12 per cent of the patients.

Duration of symptoms before admission and "doctor's delay"

Thirty-nine per cent of the patients had experienced symptoms for less than 1 month before admission, 23 per cent complained of symptoms with 1 to 2 months duration and 26 per cent with 2 to 6 months duration.

The time which elapsed between the first contact with the physician and the institution of treatment ("doctor's delay") was less than 1 month in 50 per cent of the cases, 1 to 2 months in 20 per cent and 2 to 4 months in 16 per cent of the patients. No difference was found between the different tumor sites as to the time elapsed from the occurrence of symptoms until the institution of treatment.

Treatment

Local resection of the lesion was performed in seven patients (5 per cent) as shown in Table 2, local resection with inlay of bone graft in six (4 per cent) amputation on the skeletal part harboring the lesion in 39 (2 per cent), amputation through a proximal situated skeletal part in 26 (17 per cent) amputation by exarticulation of the proximal joint in 25 (16 per cent) hemipelvectomy in two (1 per cent) and forequarter amputation in four patients (3 per cent). The neoplasm was not macroscopically removed in 4 patients (29 per cent).

Table 1 The percentage distribution of genuine osteosarcoma according to tumor size on admission and primary localization

Tumor diameter in cm	Site 1	Site 2	Site 3
<2	2.7	0	5.9
2-5	21.6	8.2	5.9
5-10	51.4	42.3	35.3
>10	24.3	49.5	52.9
	100.0	100.0	100.0

Site 1=radius, ulna, tibia, fibula and foot skeleton.

Site 2=humerus, scapula and femur

Site 3=rib, mandible, skull, spine sacrum and pelvis.

Table 2 The distribution of the patients with genuine osteosarcoma according to treatment primary tumor localization and survival

Kind of treatment	Site 1	Site 2	Site 3	Survival
Amputation	3	1	3	See Figure 5
+ bone grafting	1	3	2	
Amputation on the involved skeletal part	0	38	0	See Figures 5 and 6
+ excision of lymph nodes	0	1	0	2 months
Amputation on the proximal skeletal part	25	0	0	See Figures 5 and 6
+ excision of lymph nodes	1	0	0	8 months
Stimulation	2	23	0	See Figure 6
Quarter amputation	0	4	0	4, 7, 9 and 151 months
Minor	0	2	0	11 and 18 months
Macroscopically removed	5	27	12	See Figure 5
	37	99	17	

Chemotherapy was instituted primarily in 1 per cent of the patients and palliatively in 14 per cent of the patients with pulmonary metastases in 14 per cent. Combined chemotherapy and radiation treatment was given in 1 per cent of the patients.

Treatment according to Cade (1947), i.e. primary high-dose radiation treatment followed by amputation 6 months later in patients without pulmonary metastases, was performed in 18 per cent of the patients. Radiation treatment alone was given in 22 per cent of the cases, almost all of these were planned to receive a complete Cade treatment but succumbed with pulmonary metastases before ablative surgery could be undertaken. In 12 per cent of the patients radiation treatment was given postoperatively.

Prognosis in relation to tumor localization and treatment

The overall survival rate for all genuine osteosarcoma patients differed significantly from that obtained for patients grouped with respect to tumor localization and kind of treatment. The overall 2-year survival rate was 31 per cent, and the overall 5-year survival rate was 22 per cent (Figure 3). Patients with a peripheral localization of the neoplasm (Figure 4, site 1) had a

significantly better prognosis than those with more centrifugal tumors (sites 2 and 3). The 5-year survival rate for patients with site 1 tumors, i.e. lesions located distally to the knee and elbow joints, was 47 per cent, that for patients with site 2 tumors i.e. lesions in the

OSTEOSARCOMA

RATE OF SURVIVAL

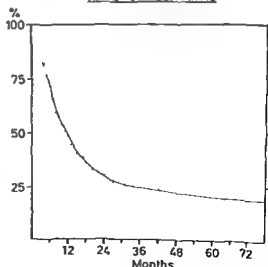


Figure 3 Rate of survival of all 153 patients with histopathologically verified primary osteosarcoma recorded in the Swedish Cancer Registry for the years 1958 through 1968

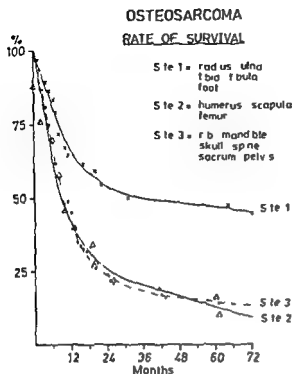


Figure 4 Rate of survival of the osteosarcoma patients according to tumor site. Patients with peripheral tumors (site 1) had a significantly ($P < 0.001$) better survival rate than those with tumors of the femur, humerus and scapula (site 2) or axial tumors (site 3). The symbols indicate survival percentage at each point of analysis (the same as in Figures 6 and 7).

humerus, scapula and femur 13 per cent, and that for site 3 tumors, i.e. lesions in the ribs, mandible, skull, spine, sacrum and pelvis, 15 per cent. While the better prognosis of site 1 tumors in relation to that of site 2 and site 3 tumors was statistically highly significant ($P < 0.001$) no significant difference was found between site 2 and site 3 tumors. The 2-year survival rates for patients with the three different tumor localizations were 54, 25 and 24 per cent, respectively. Although the tumors of site 1 were somewhat smaller than those of sites 2 and 3 the different prognoses were apparently associated with the type of treatment used and not so much with differences in tumor aggressiveness.

When the prognosis was related to the kind of treatment instituted (Table 2 and Figures

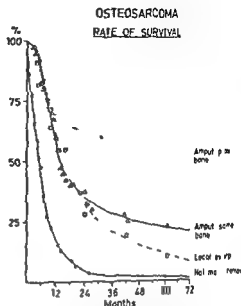


Figure 5 Rate of survival of the osteosarcoma patients according to the extent of surgery treatment performed. Patients amputated above the joint to the involved skeletal part had significantly ($P < 0.001$) better survival rates than those treated with amputation on the involved skeletal part or local extirpation of the bone. Those who did not have their tumor macroscopically removed.

5 and 6), amputation on the skeletal part proximal to that harboring the neoplasm was associated with a significantly better prognosis than other kinds of treatment (Figure 5). Thus, patients who had undergone amputation above the joint proximal to the involved skeletal part showed a 5-year survival rate of 55 per cent (site 1 tumors), those amputated on the involved skeletal part 22 per cent (site 2 tumors), those treated with local extirpation of the tumor 11 per cent, and those in whom the lesion was not macroscopically removed 1 per cent. The 2-year survival rates were 62, 35, 32 and 5 per cent, respectively. Thus, ablative surgery, also local extirpation of the tumor, was associated with a definitely better prognosis than non-operative treatment. The better prognosis for patients treated with amputation (site 1 tumors) than for those amputated on the involved skeletal part (site

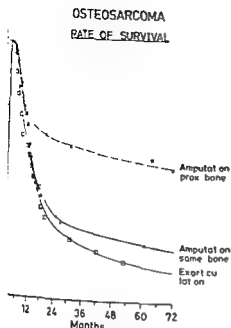


Figure 6 Rate of survival of the osteosarcoma patients in relation to the level of the ablative surgery performed. Patients amputated above the proximal to the involved skeletal part had a significantly ($P < 0.001$) better survival rate than those treated with amputation on the involved part or exarticulation. Patients who had undergone hip exarticulation did not have a better survival rate than those amputated on the involved part.

was statistically highly significant ($P < 0.001$). Patients who had undergone amputation on the involved skeletal part had a significantly ($P < 0.001$) better prognosis than those who had received non-operative treatment.

prognosis in relation to the level of surgery performed is shown in Figure 6. While patients who had undergone amputation (site 1 tumors) showed a significantly better prognosis than those treated with amputation on the involved part (site 2 tumors) exarticulated (with site 2 tumors predominantly) seemed to have a bad prognosis. The 5-year survival rates for these categories of patients were 55, 22 and 14 per cent, respectively.

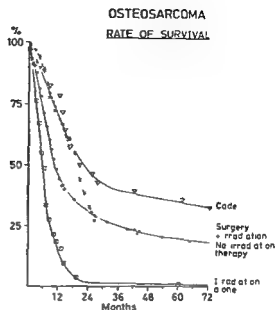


Figure 7 Rate of survival of the osteosarcoma patients treated with irradiation alone. Patients treated with irradiation alone were scheduled to undergo treatment according to Cade but succumbed with pulmonary metastases before ablative surgery could be undertaken. Patients who had received a complete Cade treatment had survival rates comparable to those treated with primary ablative surgery alone.

Patients who had received radiation treatment alone showed a very poor prognosis (Figure 7), the 5-year survival rate was less than 1 per cent. Some patients in this group had very advanced tumors already at the time of diagnosis. This group also included cases who initially were scheduled to receive treatment according to Cade, but pulmonary metastases occurred before surgery could be instituted. Patients who had undergone a complete Cade treatment showed a 5-year survival rate of 35 per cent. The corresponding figure for those primarily treated with ablative surgery was 21 per cent. The combined group of patients consisting of those who had undergone a complete Cade treatment and those who had received radiation treatment alone showed a

very poor prognosis (Figure 7), the 5-year survival rate was less than 1 per cent. Some patients in this group had very advanced tumors already at the time of diagnosis. This group also included cases who initially were scheduled to receive treatment according to Cade, but pulmonary metastases occurred before surgery could be instituted. Patients who had undergone a complete Cade treatment showed a 5-year survival rate of 35 per cent. The corresponding figure for those primarily treated with ablative surgery was 21 per cent. The combined group of patients consisting of those who had undergone a complete Cade treatment and those who had received radiation treatment alone showed a

significantly lower 5-year survival rate than those who primarily were treated surgically.

Chemotherapy with cyclophosphamide was given as an adjuvant after amputation in a limited number of patients. Although the data did not demonstrate a significant effect of this treatment upon the prognosis, a slight tendency towards an improved prognosis was found. Ten patients received local perfusion of the involved extremity with very high doses of cyclophosphamide prior to amputation. Three of these patients survived for more than 5 years.

Influence of diagnostic procedure upon prognosis

The various diagnostic procedures used in the present series were found not to exert any statistically significant effect upon the prognosis. Using multiple regression analyses it was not possible to demonstrate any significant influence, upon the prognosis of the different diagnostic procedures used, e.g. frozen section and surgery primarily, biopsy and surgery secondarily in a bloodless field, biopsy and surgery secondarily without a bloodless field, and surgery primarily without biopsy.

DISCUSSION

The 5-year survival rate of 22 per cent in all genuine osteosarcomas of the present series corresponds very well with the 23 per cent survival rate in the Mayo Clinic series (Dahlin & Coventry 1967), but is lower than the 28 per cent reported for the series from South-West England (Price 1962) and the 34 per cent recorded in an early American series (Coley & Pool 1940). However, the 5-year survival rate in our series is definitely higher than the 11 per cent recorded at the Memorial Centre for Cancer in New York between 1925 and 1955 as reported by McKenna and his colleagues (1966) who excluded patients dying after 5 years follow-

up, and the 15 per cent survival rate recorded at the Massachusetts General Hospital from 1920 to 1962 (Weinfeld & Dudley 1962).

Patients with small tumors had somewhat better prognosis than those with large ones. However, the majority of the patients had large tumors on admission or 12 per cent presented with lesions less than 5 cm in diameter. Involvement of the surrounding soft tissues by the tumor had marked effect upon the prognosis. Patients with soft-tissue involvement had a 5-year survival rate of only 18 per cent compared with 39 per cent in patients who had no soft tissue involvement. However, the latter group of patients constituted only 18 per cent of the former 82 per cent, indicating that a vast majority of the patients had advanced neoplasms on admission, although 61 per cent had experienced symptoms for less than 6 months. Nevertheless, the prognosis may improve if diagnosis can be made at an early stage of the disease. The 5-year survival was found to be better in patients with a long history of symptoms than in those with a short history of symptoms.

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Readily accessible osteosarcomas suitable for surgical treatment, e.g. peripheral tumors, are generally considered to carry a better prognosis than non-excisable, e.g. axial tumors (Lockshin & Higgins 1968). The clinical distribution of osteosarcoma is similar in different reports and that of the present series does not deviate markedly. Thus, 43 per cent of the tumors were located in the distal femur and 14 per cent in the proximal tibia. The peripheral tumors are located distally to the joints of the knees and elbows carried a significantly better prognosis than those situated in femur, humerus and pelvis, the 5 year survival rates being 47 and 33 per cent, respectively. On the other hand the corresponding figure of 15 per cent obtained for the axial tumors did not differ significantly from that of the tumors situated in the femur and humerus. Although surgically accessible, the latter osteosarcomas were carried as poor a prognosis as did the axial tumors. The two categories of lesions showed no difference with regard to parameters such as tumor size and duration of symptoms on admission.

The 47 per cent 5-year survival in osteosarcomas situated distally to the joints of the knees and elbows is better than the corresponding figure of 36 per cent reported for Mayo Clinic series which showed a 10-year survival rate of 27 per cent (Dahlin & Coventry 1967). The peripheral tumors of the present series also showed a better prognosis than that reported earlier for tumors of the knee (Coley & Pool 1940, Dahlin & Coventry 1967, McKenna et al 1966, Price 1966, Unfeld & Dudley 1962). On the other hand, the 5-year survival rate of 13 per cent for the osteosarcomas of the femur and humerus in the present series is less than the 16 to 21 per cent rate reported in the studies cited above. For the axial tumors, the survival rate of 15 per cent is somewhat higher than the 5 to 13 per cent rate recorded in the earlier series. Apparently, the neoplasms of the femur and humerus of the present series were more malignant than earlier considered.

It is evident from the data of the present

study that primary amputation above the joint proximal to the involved skeletal part is the best treatment for tumors situated distally to the joints of the knees and elbows, i.e. site 1 tumors, giving a 5-year survival rate of 55 per cent. Thus unexpectedly high survival rate makes the rationale of using combined primary chemotherapy with drugs like adriamycin, methotrexate, cyclophosphamide, vincristine and L-phenylalanine mustard questionable for patients with these peripheral lesions, when the serious toxic effects of these agents are taken into consideration. In addition, chemotherapy does not seem to prevent the late occurrence of metastases. For tumors of the femur and humerus (site 2) and for axial tumors (site 3), primary multi-cytostatic treatment appears to be indicated because of the minor effect upon the prognosis resulting from surgical treatment alone. The results of our series indicate that amputation or exarticulation as well as hemipelvectomy or forequarter amputation, offer relatively little to the final outcome in these patients, except for some palliation. It has not been shown earlier whether disarticulation at the hip is preferable to amputation through the upper part of the femur for osteosarcomas of the distal portion of the femur (Dahlin 1967). Our data indicate that the more mutilating hip disarticulation does not give a better prognosis than amputation on the proximal femur. The possibility of spread of osteosarcoma in the bone marrow must then be checked carefully. In the present series, 6 per cent of all patients had local recurrence of the tumor. Perfusion of the involved extremity with high doses of cytostatic agents prior to amputation might improve prognosis, as suggested by our data. Radical local excision should be employed whenever possible only for tumors not localized to the extremities. Radiation therapy did not affect the prognosis favorably in the present series. Consequently, treatment according to Cade (Cade 1947) cannot be recommended. Ten patients of our series had undergone pulmonary resection because of metastases occurring after the primary

significantly lower 5-year survival rate than those who primarily were treated surgically.

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The prognosis was not significantly affected by the various diagnostic procedures applied. It was not possible to demonstrate any positive effect upon the 5 year survival rate of primary surgical treatment subsequent to freeze-section diagnosis in comparison with biopsy and secondary surgical treatment after definite histopathological diagnosis had been obtained. It has been recommended that biopsy of suspected lesions should be performed without tourniquet to avoid flushing of the tumor cells from the marrow cavity (Allen & Stevens 1973).

- Sweden 1959-1965, Stockholm, Göteborgs 94 cases observed at the M.
Boktryckeri AB General Hospital from 1951 to 1965
M. M. S. & Dudley, H. R. (1962) *Jt Surg* 44-A, 269-276
osteogenic sarcoma A follow-up study of the

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Figure 1 Case A Typical facial features (nasal depression, hypertelorism, frontal prominence, temple cranium)



Figure 2 Case A Lateral view of facial features

Hips Bilateral luxation (Figure 4), no pain. Acceptable mobility, flexion to 90° on the right and to 80° on the left. External rotation deformity in the left hip, unlimited marching radius.

Knees On the right side, good mobility without deformities. On the left side, complete extension, flexion to 10° , rotation of tibia on femur with luxation (Figure 5). Bilateral patellar hypoplasia.

Feet Left pes equino-varo-adductus right pes plano-valgus. Both feet painless.

Case B J.A.P.A., male, 14 years old born at term forceps. Defects observed since birth. One parent affected (Case A).

Examination

Typical facial features (Figure 6).
Shoulders Limitation of mobility, no luxation.
Elbows Bilateral contracture in 90° flexion. Flexion of 60° in the right elbow and 25° in the left elbow. Bilateral luxation since birth (Figure 7).
Hands and wrists No deformities, good mobility.
Neck Slight left torticollis.

Vertebral column Normal save for discrete dorso-lumbar scoliosis.

Hips Good mobility, flexion to 100° bilaterally. No contractures or deformities. At present, bilateral subluxation (Figures 8 and 9).

Knees No deformities and good mobility on the right side. On the left side, flexion to 25° and complete extension.

Feet Right pes plano-valgus left pes equino-varo-adductus with marked deformity (Figure 10).

Case C M.I.P.A., female, 11 years old born at term, breech presentation. Deformities observed since birth. Sister of case B and daughter of case A.

Examination

Typical facial features (Figure 11).
Shoulders Normal.
Elbows Bilateral limitation of extension by about 5 to 10° . Bilateral luxation of caput.
Hands Normal.
Neck Right moderate torticollis.

LARSEN'S SYNDROME

Report of Three Cases in the One Family, Mother and Two Offspring

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G FDEZ DIEZ DE MIGUEL

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Three cases are presented of the very rare Larsen's syndrome being on the second report in the literature of concomitant involvement of parent (the mother in this instance) and offspring (two children) (see also Haberman et al 1976)

The only therapeutic procedure that is applicable i.e. surgery has given only mediocre results over an evolutive period of 8 to 9 years (in case C)

We have not been able to demonstrate analytical or histologic abnormalities that might provide a diagnostic clue ■ that the aetiopathogeny of the disorder remains unknown

Key words Larsen's syndrome, articular luxations heredity

Accepted 3 iv 78

Since 1950, when Larsen and co-workers described as a nosological entity the group of signs and symptoms constituting this disorder, very few cases have been reported in the literature, and very few variations have been added to the original clinical, analytical and radiological description

As regards the aetiopathogeny of the disorder, the majority of authors (Almquist et al 1969, Boni ■ al 1974, Steel & Kohl 1972) concur that it must be a generalized mesenchymal alteration This opinion, however, has not been proven to date

The possible hereditary character of the disorder has also been the subject of discussion, and the cases reported have been inconclusive in this respect Some do not show a hereditary trend (Larsen et al 1950, Lee 1973), some exhibit recessive heredity (Curtis & Fisher 1970, Steel & Kohl 1972, Latta et al 1971), and some show definite dominant heredity (McFarlane 1947)

In the cases we now present there is no doubt about the hereditary character but it has not been possible to determine the responsible gene and the type of heredity

CASE REPORTS

Case A MIAA, female 34 years old born normally at term after an uneventful pregnancy Defects observed since her birth. No family history

... ..

Examination

Typical facial features (Figures 1 and 2)
Shoulder good mobility, no pain
Elbows Complete flexion Bilateral limitation of extension of 20 to 30° Bilateral luxation (Figure 3)
Hands Short fingernails otherwise normal
Vertebral column Moderate right dorso-lumbar scoliosis (sleeps with a stiff board under the mattress)



6 Case B Typical facial features Discrete left torticollis



7 Case B Bilateral flexion contracture of the elbows and visible deformities of the left foot



8 Case B Hips (1966 age 4 years)



9 Case B Hips at present Bilateral subluxation



Figure 3 Case A Left elbow Superior cubito humeral and radio-cubital luxation. The disorder is bilateral.



Figure 5 Case A Left knee Femoro-tibial luxation.



Figure 4 Case A Bilateral luxation.

Table 1 Typical deformities

	Case A	Case II	Case C
<i>cranium</i>			
<i>lus</i>	—	—	—
<i>defect</i>	—	—	—
<i>depression</i>	+	+	+
<i>ism</i>	+	+	+
<i>prominence</i>	+	—	—
<i>ocular luxations</i>			
<i>es</i>	+	+	+
<i>l</i>	+	Subluxation	+
<i>l</i>	+	+	+
<i>ulders</i>	—	—	—
<i>rns</i>	+	+	Subluxation of the caput radii
<i>feet and hands</i>			
<i>multiple carpal ossifying nuclei</i>	+	+	+
<i>phalangeal luxations</i>	—	+	—
<i>or anomalies (supernumerary pts, syndactyly, "delta" phalanges)</i>	—	—	—
<i>vertebral column</i>			
<i>iosis</i>	+	±	+
<i>mental anomalies</i>			
<i>pina bifida</i>	+	+	+
<i>rologic disorders</i>	—	—	—
<i>ribs</i>			
<i>ble ossification nucleus in the calcaneum</i>	Not able to be evaluated due to definitive fusion	+	
<i>erlaxitude</i>	—	—	
<i>ital retardation</i>	—	—	—
<i>is, or present</i>			
<i>crete</i>			

Age 2 years Right hip, open reduction
wed by pelvi-pedic plaster cast
action was impossible, and the luxation
ists to date, with deformity of the femoral
t, but with acceptable function
all surgical procedures, the pathological
y of the soft tissue samples was in-
lusive as to diagnosis

LABORATORY RESULTS

Case A

Blood (white and red cell count, differential
white cell count, erythrocyte sedimentation
rate) normal Urine analysis and urinary
sediment without pathological findings



Figure 10 Case B Feet at present. Marked deformities.



Figure 11 Case C Typical facial features. Marked right torticollis.

Vertebral column: Normal save for slight right dorsal structural scoliosis.

Hips: Bilateral luxation. Flexion contracture of 20° bilaterally. Limited mobility with flexion to 70° on the right and 80° on the left.

Knees: On the right side flexion contracture of 20° flexion to 20° . On the left side complete extension flexion to 15° . Discrete deformities.

Lower extremities: Dismetry with shortening by 2.5 cm of the left lower extremity.

Feet: Right pes plano-valgus, left pes equino-varo-adductus.

All these procedures were carried out prior to the patient's first visit to our hospital so that we lack all data. In any case, they may be considered as failures on the evidence of the present state of the areas involved.

At age 6 years Sternocleidomastoid tenotomy because of congenital left-sided torticollis. The torticollis persists at present although it is markedly reduced.

Case C

At age 12 months Right knee open reduction of the luxation stabilization with Kirschner wires, and lengthening of the quadriceps femoris thereafter postural plaster cast. On the left knee a similar procedure save for lengthening of the quadriceps which was not carried out. At present there is no luxation (which was so evident before surgery) although distal postural defects persist and there is very limited mobility.

SURGICAL PROCEDURES

Case A

On the left foot. The patient does not remember date or type of procedure.

Case B

At 18 months, on the left foot. At 24 months, on the right foot. And at 36 months on the left knee.

TELANGIECTATIC OSTEOSARCOMA

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Of the 242 cases of osteosarcoma recorded in the Swedish Cancer Registry for the years 1958 through 1968 only one was found to represent telangiectatic osteosarcoma. Another case was recently diagnosed in our department. The characteristic morphologic features of these neoplasms were anaplastic stroma, high mitotic activity, osteoid formation, widely anastomosing blood spaces, and alkaline phosphatase activity. The experience gathered indicates that telangiectatic osteosarcoma constitutes a histopathologic variant of genuine osteosarcoma with a serious prognosis, necessitating the same kind of treatment as for the genuine tumour.

Key words: bone neoplasms, diagnosis, telangiectatic, histopathology.

Accepted 21 III 78

Opinions differ in the literature as to the existence of a special type of osteosarcoma which merits the designation telangiectatic osteosarcoma, and the clinical significance of this kind of tumour is also disputed. It is well known that differentiation between telangiectatic osteosarcoma and other bone tumours with rich vascularization often is difficult, and this is particularly true for the differentiation between telangiectatic osteosarcoma and aneurysmal bone cysts. Because of these difficulties in differential diagnosis, Jaffe et al (1977) used computerized discriminant analysis for the study of nuclear mitotic index, cellularity and nuclear content and thus facilitated differentiation between these tumours.

The prognosis of telangiectatic osteosarcoma has been reported not to differ from that of other kinds of osteosarcoma (Jaffe & Marcove et al 1970, Farr et al 1974, Sjunno et al 1976, Spjut et al (1970)). There is no need for subclassification of

osteosarcomas into sclerosing, osteolytic, telangiectatic or medullary types because of a lack of prognostic significance of such a differentiation.

Because of the existence of these differing opinions and diagnostic difficulties we found it worthwhile in our studies of malignant primary bone tumours, to pay attention to tumours which might represent telangiectatic osteosarcomas. Among all the tumours which we have studied there have only been two which are of interest in this context. These cases are reviewed in the present study.

PATIENTS AND METHODS

Case 1 was recently treated at our clinic and Case 2 was found during our review of all osteosarcomas recorded in the Swedish Cancer Registry from 1958 through 1968 (Larsson et al 1978).

Case reports

Patient 1. A 14-year-old boy was admitted on January 9, 1976 because of pain in the

Urinary mucopolysaccharides 26 U c.p.c per gramme of creatinine (normal) Blood biochemistry in the SMA 12 analytical series (transaminases, lactic dehydrogenase, alkaline phosphatase, albumin, bilirubin, total proteins, cholesterol, calcium, inorganic phosphorus, uric acid, blood urea nitrogen, glucose) within normal ranges. Karyotype 46 XX (normal)

Case B

Blood, urine and urinary sediment (as above) normal, blood biochemistry (as above) Alkaline phosphatase 204 mU per millilitre, inorganic phosphorus 56 mg per 100 millilitres the remainder of values within normal ranges. Urinary mucopolysaccharides 147.2 U c.p.c per gramme of creatinine Karyotype 46 XX (normal)

Case C

Blood, urine and urinary sediment (as above) normal, blood biochemistry (as above) Alkaline phosphatase 147 mU per millilitre, inorganic phosphorus 55 mg per 100 millilitres, the remainder of values within normal ranges. Urinary mucopolysaccharides 76.3 U c.p.c. per gramme of creatinine Karyotype 46 XX (normal)

DISCUSSION

In the cases presented here there is no doubt as to the presence of hereditary factors which are not always present in this syndrome. However, the analytical studies performed yielded normal results, as in practically all cases in the literature, so that the aetiology of the disorder remains unknown.

It is interesting to point out the absence of

pain or neurological signs in spite of the very marked morphological alterations.

Furthermore, ambulation is no problem: in the three cases presented, crutches, canes or other aids are not required. The marching radius is not limited.

Surgery has only a relatively limited role in the treatment of this disorder. Apart from the technical difficulties involved, recurrences or residual joint rigidity are frequently encountered. We are therefore faced with a nosological entity presenting great difficulties from the viewpoint of medico-surgical treatment.

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. However on April 3, 1965, pulmonary angiograms revealed the occurrence of emboli. Despite palliative chemotherapy with phosphamide there was progression of the static lesions and the patient died on July 9, in pulmonary insufficiency

needle aspiration biopsy

Material obtained at fine needle aspiration biopsy (Figure 3) from patient 1 disclosed sheets of polymorphous cells. Some of these were of spindle-shaped, fibroblastic type, whereas others were rounded, oval or irregular (Figure 3A). Chromatin density of the nuclei varied. One feature of nuclei of varying size could be observed. Mitotic figures were seen among the polymorphous cells (Figure 3B). The amount of cytoplasm varied, in most cells there was a moderate amount of cytoplasm which showed moderate staining. Cytoplasmic granulation and vacuolation were seen in some cells. Some multinucleated giant-cells were encountered (Figure 3C). The nuclei were usually rounded or oval and varied slightly in size and chromatin affinity. Rather small and moderately sized nucleoli were observed in these cells. A

moderately dense cytoplasm with fine granulation was seen. The outline of the giant-cells was usually irregular

Light microscopy

The tumours from both patients were fixed in 10 per cent neutral formalin. The following stains were applied: haematoxylin-eosin, van Gieson's stain, periodic acid-Schiff (PAS) and Laidlaw's silver impregnation. In addition alkaline phosphatase activity was studied using the method of Barka & Andersson (1963).

At re-examination, essentially similar findings were made in both cases. Low power field examination disclosed polymorphous tumours with a rich number of widely anastomosing blood spaces of varying size and shape. The solid areas exhibited osteoid formation (Figure 4). The amount of osteoid varied considerably in different parts of the same tumour. Tumour bone or cartilage were not seen.

The solid areas were mainly composed of polygonal cells with a moderate or high polymorphism. In addition some areas exhibited



Figure 3A Fine needle aspiration biopsy showing polymorphous and polychromatic tumour cells, some of which are spindle shaped. May-Grunwald Giemsa stain $\times 520$ (patient 1)

Figure 3B Mitotic figure in one tumour cell. May-Grunwald Giemsa stain $\times 560$ (patient 1)

Figure 3C Multinucleated giant-cell with rounded or oval nuclei and a moderate amount of cytoplasm. May-Grunwald Giemsa stain $\times 520$ (patient 1)

the nuclear membranes distinct. Mitotic figures were frequently encountered. Many of these were atypical.

A few multinucleated giant-cells were observed (Figure 6). They possessed medium-sized rounded or oval nuclei with moderately distinct chromatin and medium sized nucleoli. The cytoplasm exhibited a moderate density and occasionally small vacuoles. The outline was usually irregular.

The blood spaces varied considerably in size



Figure 4 Blood spaces containing some seemingly desquamated tumour cells. Osteoid is seen in solid areas. Haematoxylin-eosin $\times 80$ (patient 1)



Figure 1 Radiographs revealing a destructive lesion involving the medial portion of the distal femur and causing subperiosteal new bone formation (patient 1)



Figure 2 Angiographs showing hypertastal with non-homogenous accumulation of contrast medium and a large number of pathological vessels (patient 1)

part of the left knee of 2 months duration. There was no history of antecedent trauma. Physical examination revealed a firm swelling that was fixed to the medial femoral condyle. The regional lymph nodes were not involved. The erythrocyte sedimentation rate was 55 mm per hour. Other routine laboratory analyses were normal.

Roentgenograms showed a 6 cm long destructive lesion in the distal and medial part of the left femur (Figure 1). A soft tissue tumour could be seen outside the area of bone destruction. Angiography revealed a highly vascularized tumour with an abundance of tortuous vessels in the destroyed part of the femur, and also in the surrounding soft tissues (Figure 2). A pulmonary roentgenogram and a scintigram of the liver were normal.

Fine needle aspiration biopsy disclosed polymorphous, partly spindle-shaped mesenchymal cells and a few multinucleated giant-cells (see below).

performed on the lesion in the distal femur. The tumour was so highly vascularized that it was very difficult to achieve haemostasis, and there was a total blood loss of 1800 ml. The histopathological diagnosis was telangiectatic osteosarcoma (see below).

On January 30, 1976 an amputation of the left femur was carried out, 15 cm below the greater trochanter. Three weeks postoperatively chemotherapy with Adriamycin* was instituted at a dose

of 105 mg as single injections given every 14 days over a 6-week period. He was fitted with a prosthesis and could return home.

Despite the treatment, roentgenograms revealed the occurrence of pulmonary metastases in November 1976. He died in pulmonary insufficiency on December 27, 1976.

Patient 2 A 16-year-old boy was admitted February 20, 1965 because of successively increasing pain of 14 days duration localized to left knee region around the proximal part of fibula. Physical examination showed a 10 x 10 cm large, tender swelling over the head of the fibula. There was no involvement of the regional lymph nodes. Routine laboratory investigations were normal including the sedimentation rate. Roentgenograms revealed a destructive lesion involving the whole proximal part of the fibula. A pulmonary roentgenogram was normal.

On March 4, 1965, a cystic chocolate-brown, easily bleeding soft tumour was excised. The bone was completely destroyed by the tumour; there was no major extension into the surrounding soft tissues. The operation was performed in a bloodless field. There was no excessive bleeding when the tourniquet was released.

The histopathological appearance of the removed specimen was difficult to interpret. It resembled an aneurysmal bone cyst or a giant-cell tumour of bone, but was considered but the final diagnosis was telangiectatic osteosarcoma (see below).

Postoperative high-energy radiotherapy

Another case was recently diagnosed in our department. Telangiectatic osteosarcoma thus constitutes, in the most, no more than 2 per cent of all types of osteosarcoma. With a yearly incidence of 2.8 cases of osteosarcoma per million people in Sweden (Larsson & Lorentzon 1974a) telangiectatic osteosarcoma is very rare, the yearly incidence being about 5.6 cases per 100 million people. There was a male predominance with a ratio of 1.91 in the series of Farr et al (1974), while for all types of osteosarcoma we found a sex ratio of 1.41 (Larsson & Lorentzon 1974b). Except for a less common involvement of the tibia the data published by Farr et al (1974) indicated no difference in regards the clinical course between telangiectatic osteosarcoma and genuine osteosarcoma as a group. The cure rate was approximately 18 per cent. The clinical

course in the knee region, and either increased or normal sedimentation rate. Roentgenograms showed a destructive lesion similar to that of genuine osteosarcoma. Angiography, carried out in Case 1, showed a richly vascularized tumour. The rich vascularization was further demonstrated by the presence of profuse bleeding at biopsy. Most like bleeding directly from the femoral artery. Case 2 did not exhibit such profuse bleeding at operation, although, at light microscopy, the tumour was as vascularized as that of Case 1. The use of a tourniquet in Case 2 and the more peripheral location of the lesion in the proximal fibula might explain the observed difference in bleeding from the tumours.

Characteristic light microscopic features of the tumours in our cases were anaplastic stroma, high mitotic activity, osteoid formation, widely anastomosing blood spaces and alkaline phosphatase activity. Multinucleated giant-cells were rather sparsely represented. The morphological findings and the clinical course indicate malignancy. Because of the light microscopic characteristics the histopathological diagnoses which primarily

should be considered are osteogenic sarcoma on the one hand and aneurysmal bone cyst on the other hand. Although genuine giant-cell tumours may produce osteoid (Murphy & Ackerman 1956, Shuffstall & Gregory 1953, Williams et al 1954) and also may be rich in blood vessels, there was no evidence in our cases of giant-cell tumour. The anaplasia in our tumours was characteristic of a sarcomatous tumour such as osteosarcoma, and reduced the possibility of it being an aneurysmal bone cyst. This opinion is also held by Clough & Price (1968) and Tillman et al (1968). The latter authors have also suggested that the presence of irregular tumour osteoid indicates telangiectatic osteosarcoma rather than aneurysmal bone cyst. Based upon these findings we maintain that telangiectatic osteosarcoma can be differentiated from other bone lesions. The alkaline phosphatase activity found in our tumours also suggests osteosarcoma. Fine needle aspiration biopsy suggested malignant bone tumour in our cases but did not help in the differentiation of the lesion.

Reed & Rothenberg (1964) have proposed that the vascularity pattern of aneurysmal bone cysts is a non-specific reaction representing a primary lesion; whereas vascularity of other bone tumours represents a late secondary change. The finding in our cases of seemingly desquamated tumour cells in the lumina, and the absence in many blood spaces of an endothelial lining, might indicate a secondary nature of the blood spaces. It is of interest that we have observed a similar rich vascularization in experimentally produced mouse osteosarcoma (Larsson et al unpublished). Osteosarcoma containing a rich amount of blood filled cysts has also been described in a dog (Price & Sumner-Smith 1966).

Angiographically, telangiectatic osteosarcoma is hypervascularized as most of the osteosarcomas. Genuine giant-cell tumour of bone and some of the aneurysmal bone cysts are also hypervascularized (Lundstrom et al 1977) which in some cases could make differential diagnosis difficult. As in all cases

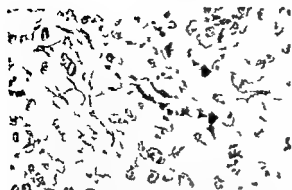


Figure 5 Solid tumour area showing oval or slightly irregular nuclei with one or more distinct nucleoli (arrows). Mitotic figures are seen. Haematoxylin-eosin $\times 500$ (patient 1).

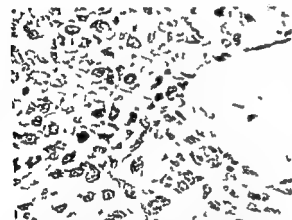


Figure 6 Blood space lined by endothelial like cells. The solid area exhibits polymorphism, polychromasia, one multinucleated giant cell (G) and mitotic figures. Haematoxylin-eosin $\times 500$ (patient 1).

and shape. Erythrocytes were found in the lumina (Figure 7). Most blood spaces were lined by flattened cells of endothelial type (Figure 6) whereas no such lining was found in other blood spaces (Figure 7). Still other spaces were surrounded by rounded or cuboidal cells. Evident alkaline phosphatase activity was found in the tumours (Figure 8).

DISCUSSION

Telangiectatic osteosarcoma was considered by Ewing (1922, 1939) to be a distinct clinical and pathological entity. However, recent reviews (Dahlin 1967, Jaffe 1956, Marcove et



Figure 7 Irregular blood spaces with endothelial lining. Erythrocytes are seen in the lumina. The solid areas are moderately polymorphous. Van Gieson's stain $\times 50$ (patient 2).

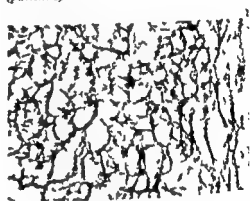


Figure 8 Alkaline phosphatase activity in the tumour area $\times 500$ (patient 1).

al 1970, Price & Sumner-Smith 1966) designate telangiectatic osteosarcoma as a histopathological variant of osteosarcoma with no special clinical significance. This opinion was also supported in the review of Farr and co-workers (1974). The frequency of telangiectatic osteosarcoma has not been dealt with in previously published large series of osteosarcoma. In the recent study by Farr and co-workers (1974) only 29 patients with telangiectatic osteosarcoma could be found among a total of 1480 cases of osteosarcoma, i.e. 2 per cent. In our review (Larsson et al 1978) of all 242 cases of osteosarcoma recorded in the Swedish Cancer Register during the years 1958 through 1968 we found only one case which warranted sub-classification as telangiectatic osteosarcoma.

DESTRUCTION OF A TUBERCULOUS THUMB BY BONE GRAFTING

A Report

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Tuberculosis with secondary staphylococcal infection destroyed the right thumb and index phalanges of a 24-year-old farmer. Four months after starting antibiotic therapy the index finger was amputated, and the thumb reconstructed by excising the disorganized phalanges and transferring the index metacarpal as a free graft to replace them. No previous report of this technique has been traced. A concurrent infection of the patient's left tarsus was treated by triple arthrodesis.

Key words: tuberculous thumb, reconstruction, index metacarpal, free graft

Accepted 4 v 78

CASE REPORT

The 24-year-old farmer

...tuberculous osteitis with secondary infection by *Staphylococcus aureus*. Chemotherapy with Streptomycin, Myambutol and Rifampicin was started, but 2 months later, although his general condition was considered improved, his hand and forearm remained unchanged.

The state of his right hand at that time is shown in Figure 1. The middle phalanx of the index finger and proximal phalanx of the thumb were completely disorganized, and the bases of the distal phalanges, and the head of the proximal index phalanx were destroyed by the infection. Multiple sinuses were present.

His general condition was good, and there were no signs of tuberculosis elsewhere but his erythrocyte sedimentation rate (Westergren) was 45 millimetres in the first hour. Chemotherapy was continued and the affected hand immobilized in a plaster cast. Two months later all sinuses were healed and his sedimentation

Because of the extensive phalangeal destruction and consequent instability of the right thumb and index finger it was decided to sacrifice the latter and reconstruct the thumb, the operation being carried out on June 7th, 1972, some 6 months after the first hand symptoms. Under general anaesthesia and pneumatic tourniquet a racket incision was made, encircling the base of the index finger, with its handle extending proximally along



Figure 1 The hand 4 months after the onset of symptoms

of malignant bone tumour, the final diagnosis should always be based upon a thorough evaluation of all clinical, roentgenographical and histopathological data. In view of the differences with regard to treatment and prognosis, the differentiation of telangiectatic osteosarcoma from other bone lesions, particularly benign lesions such as aneurysmal bone cyst, is very important. From our experience we agree with Farr et al (1974) that telangiectatic osteosarcoma constitutes a histologic variant of genuine osteosarcoma, with a similar serious prognosis, necessitating the same kind of treatment.

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CUTANEOUS PINNING OF SUPRACONDYLAR FRACTURES OF THE HUMERUS

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Six cases of supracondylar fracture of the humerus in children were treated by closed reduction and percutaneous pinning with two Kirschner wires inserted laterally through the capitellum of the humerus. This treatment has the same advantages as the commonly used percutaneous pinning with crossed Kirschner wires inserted through the epicondyles of the humerus, and it further eliminates the risk of damaging the ulnar nerve by the insertion of the medial Kirschner wire.

Key words: percutaneous lateral pinning supracondylar fractures of the humerus, ulnar nerve lesion

Accepted 4 v 78

Supracondylar fracture of the humerus in children, usually produced by a fall on the stretched arm, is a common fracture seen in the ages of 4 and 10 years. In nearly 50 per cent it is an extension fracture with posteriorly displaced distal fragment (Blount 1954, Holmberg 1945, Hoyer 1952, Jones 1976).

Several different methods of treatment have been recommended.

Closed reduction and plaster fixation
Closed reduction and traction
Closed reduction and percutaneous pinning

Open reduction and osteosynthesis.
Several modifications of these methods have been described (Blount 1954, Dunlop 1939, El-kawi & Fattah 1965, Hagen 1964, Hoyer 1952, Sandegård 1943, Swenson 1948).

In our report concerns six cases of supracondylar fracture of the humerus in children, all of which were closed and fixed with two percutaneous Kirschner wires inserted laterally through the

capitellum of the humerus after closed reduction, as described by Fowles & Kassab (1974).

PATIENTS AND METHODS

During the period 1974-1977 33 children between the ages of 4 and 15 years with displaced supracondylar fractures of the humerus were treated in Holstebro Central Hospital, Orthopaedic Surgical Department.

Fifteen were treated with closed reduction and plaster and one with skeletal traction. Seventeen were osteosynthesized: nine after open and eight after closed reduction. The closed reduction was in two cases followed by percutaneous fixation with two crossed Kirschner wires through the epicondyles, and in six cases with percutaneous pinning with two Kirschner wires inserted laterally through the capitellum of the humerus. These six fractures were all according to the classification of Holmberg (1945), type 4 fractures. Five were treated as emergencies and one after 48 hours due to insufficient conservative treatment.



Figure 2 Four months postoperatively showing rapid recovery of function.

the radial side of the second metacarpal to its base. The finger was disarticulated at its metacarpophalangeal joint and the distal four fifths of its metacarpal removed subperiosteally. Through a longitudinal incision on the ulnar side of the thumb the remains of the proximal phalanx, the base of the distal phalanx and the head of the first metacarpal were excised. The freed index metacarpal was trimmed by removing the distal part of its head to make a tight fit between the cut ends of the thumb metacarpal and distal phalanx. It was inserted with its original distal (broad) end facing proximally and no internal fixation was required.

The forearm, wrist and reconstructed thumb were immobilized in a plaster cast for 3 weeks, whereafter mobilizing exercises were started. Three months later excellent function was present with good opposition and pinch (Figure 2). The patient was last seen 4 years postoperatively when he was doing his normal farm work without



Figure 3 Four years after operation showing complete incorporation of graft.

significant disability. X-ray at this time shows complete incorporation of the graft (Figure 3).

COMMENT

Policization using the index finger or part of the index ray, is well established for replacing the amputated or congenitally absent thumb, but the free graft reconstruction described here as a method of replacing necrotic thumb does not appear to have been reported previously.

It is applicable only in cases of thumb destruction with intact soft tissue. Biologically it is comparable with the free rib grafts to fill the gap between vertebral bodies after anterior debridement of the tuberculous spine.

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superior ■ conservative treatment (Flynn ■
1974, Haddad et al 1970)

However, the insertion of the medial Kirschner wire involves the risk of injuring the ulnar nerve due to difficulties in locating it because of fracture oedema. This fact may lead to open reduction of the fracture, enlarging the intervention considerably (Gruber & Hudson 1964, Sandegård 1943). Furthermore, the rarely occurring congenital dislocation of the ulnar nerve heightens the risk of injuring the nerve.

Percutaneous lateral pinning seems to offer the same advantages ■ the usually performed method with crossed Kirschner wires, i.e., stable fixation of the fracture, short hospitalization, short immobilization, few operative complications and good end results. Finally both methods are quick and simple surgical interventions. However, in addition percutaneous lateral pinning has the advantage of eliminating the risk of lesion to the ulnar nerve when inserting the medial Kirschner wire (Flynn et al 1974, Haddad et al 1970, Jones 1967, Swenson 1943).

Postoperative affection of the ulnar nerve was found in both cases treated with crossed percutaneous pinning in this report. In one of the cases the ulnar nerve was partially transected when the medial Kirschner wire was removed. After primary suture the nerve function was almost fully restored. In the other case paresis of the ulnar nerve was observed for 3 months after the operation. These ulnar nerve complications could have been avoided by using percutaneous lateral pinning.

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Figure 1a, b AP and lateral radiographs showing a displaced supracondylar fracture of the humerus in a boy 8 years old

The surgical interventions are performed under general anaesthesia and with the aid of an X-ray with TV-amplifier. The fracture is reduced as described by Watson-Jones (1976).

The surgeon then with one hand holds the reduced fracture. Having palpated the capitellum of the humerus just laterally to the olecranon a Kirschner wire (size 1.25 mm in diameter) is inserted percutaneously using an automatic drill between the capitellum and the trochlea of the humerus through the fracture about 5 cm up into the medullary canal. The second wire is inserted at an angle of 30 degrees, close to the first, and

with the elbow flexed to 90 degrees and the forearm in neutral position.

After the operation the patient is confined to bed with the arm elevated for 24 hours. All the patients were out of bed on the second day and were discharged 2 to 5 days postoperatively.

X-ray examination was performed 1 and 3 weeks after the operation. All fractures had healed after 3 weeks, when plaster and Kirschner wires were removed in the out patient clinic without the use of local anaesthesia. Rehabilitation of the mobility of the elbow was started either by self-training (3 patients) or with the help of a physiotherapist (3 patients).

The children were re-examined 4 to 111 weeks postoperatively (mean 7 weeks) and finally followed up after 6 months to 3 years (mean 2 years). The results were classified according to Fowles & Kassab (1974).

Excellent a normal hand and arm

Good either a deficit of less than 20 degrees in the range of movement of the elbow or a change in the carrying angle of less than 10 degrees (if



Figure 2a, b AP and lateral radiographs of the same elbow as shown in Figure 1, after reduction, pinning and application of a plaster splint.

both abnormalities were present the patient was placed in the next category)

Fair a deficit in the range of movement of less than 20 degrees

Poor the range of movement decreased more than 50 degrees, or a change in the carrying angle of more than 20 degrees

RESULTS

At the final examination in the open ward the result in two patients could be classified as excellent, three as good and one as fair.

Six months to 3 years later the result was excellent in four cases and good in one case. The child classified as good had a varus deformity of 5 degrees.

During the observation period neither neurovascular disturbances nor infection were observed. No subjective discomfort was recorded.

One patient, who 10 weeks postoperative was classified as excellent, could not be followed up.

DISCUSSION

The treatment of supracondylar fractures of the humerus in children as described by Swenson (1948) and later by Jones (1966) with closed reduction followed by fixation with crossed percutaneous Kirschner wires through the epicondyles of the humerus, in several reports has proved



Figure 1 A 22 year old man Right shoulder
caudo-cranial view Posterior dislocation
of the humeral head

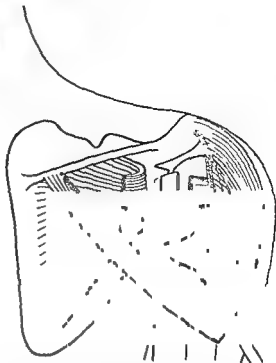


Figure 3 The deltoid is separated from the spine
of the scapula and retracted inferiorly The infra
spinatus tendon is divided and the graft in
position

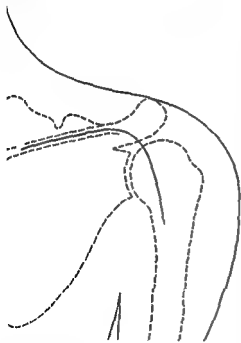


Figure 2 Posterior aspect of the right shoulder
showing the skin incision

a full range of motion and no instability could be provoked. Another of the male patients stated that during the first 2-3 years after operation he had experienced only some crepitations in the shoulder but later got a feeling of incipient locking in a certain position of the arm. He had no feeling of instability and thought himself much better than before operation. Clinical examination revealed no instability during movement but when the humerus was slightly flexed and inwardly rotated the examiner could force the humeral head somewhat backwards indicating slight instability. The sensation the patient thereby felt was not familiar to him. The mobility was normal.

The patient with general joint laxity considered himself definitely improved by the operation even if he experienced some residual instability which could be verified. A slightly decreased mobility was noted.

The 64-year-old woman reviewed 4 years

varied, 15 months in one case 30 months in one case and at least 4 years in cases

no male patients considered their shoulders to be completely normal. They had

IDIOPATHIC POSTERIOR INSTABILITY OF THE SHOULDER JOINT

Results of Operation with Posterior Bone Graft

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Five cases of idiopathic posterior instability of the shoulder joint operatively treated mainly by insertion of a bone graft are reported. The late results are satisfactory.

Key words posterior instability, shoulder joint, bone graft

Accepted 1 iv 78

Two main groups of recurrent posterior subluxation or dislocation (instability) of the shoulder joint can be recognized, the post-traumatic and the idiopathic (English & Macnab 1974).

This paper reports the results of an operation for idiopathic instability consisting mainly of insertion of a bone graft.

PATIENTS

Four men (age range 18-34 years) and a 64-year-old woman sought medical advice because of instability of the shoulder joint. In four cases the symptoms had started after minor or insignificant trauma and in this group there was an 18-year-old male alcoholic who also had general laxity of the joints. The fifth patient, a 34-year-old man had 13 years earlier sustained a football injury which was not severe enough to make him attend a doctor but after which the shoulder symptoms commenced. The patients had had symptoms varying from some months to almost 50 years.

Instability of the posterior type was diagnosed at clinical and roentgenological examination (Figure 1). The indication for operation was recurring episodes of painful instability in some cases occurring with increasing frequency. One male patient could not reduce the dislocations by himself.

OPERATIVE PROCEDURE

The approach is similar to that described by Rowe & Yee (1944), with a skin incision along the spine of the scapula, curving laterally downwards over the posterior aspect of the shoulder joint (Figure 2). The deltoid is separated subperiosteally from the spine of the scapula by sharp dissection from the lateral to the medial side where the origin is spared. The muscle is retracted inferiorly and the infraspinatus exposed. Care is taken not to damage the suprascapular and axillary nerves. The infraspinatus tendon and the capsule are divided and the posterior aspect of the glenoid well exposed. About 5 mm from the articular margin a groove is made with an osteotome to receive the transplant, which is taken from the iliac crest. The size of the transplant is about 2 x 2.5 cm and it is allowed to project 8-12 mm posteriorly over the articular surface (Figures 3 and 4). It should be placed in the middle of the posterior aspect of the glenoid and not too cranially or caudally in order to minimize the risk of recurrence of the instability. The tendon of the capsule is duplicated and the deltoid is reattached. Postoperatively the arm is immobilized in neutral position between inward and outward rotation for 4 weeks. Active exercises are then started.

RESULTS

At follow-up the patients were examined clinically and roentgenologically. Follow up

chosen in four cases out of five and in the fifth only the bone graft was used

The results can be judged as excellent in two cases and very good in one case. The other two patients considered themselves definitely improved. It is remarkable, however, that the woman thought that her shoulder was stable in spite of the instability clearly demonstrable at the clinical examination.

A fairly extensive search of the literature on idiopathic posterior instability of the shoulder joint treated with a posterior bone graft revealed several reports all with favourable results (Hohmann 1933, Asplund 1942, Tournay 1948, Jones 1958, Galli 1959, Simon 1967, Lindholm 1974) but in each report there were only one or two cases and the interval between the operation and the review was often less than a year. DePalma (1973) who has had greater experience favoured a combined procedure with a bone graft or osteotomy of the neck of the scapula supplemented by tendon shortening and reported no failures.

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Figure 4 A 34 year old man. Postoperative roentgenograms of the right shoulder
(a) A P view. The graft is clearly visible through the humeral head
(b) Vertical caudo-cranial view showing the graft and its position in the scapular neck

after operation, was satisfied considered the shoulder stable, painless and with sufficient mobility. At clinical examination the humeral head could be seen to bulge backwards during

movements either spontaneously or after slight provocation. Inward rotation was moderately decreased, otherwise mobility was normal.

In no case did the roentgenological examination reveal resorption and disappearance of the graft.

DISCUSSION

A division of posterior dislocations and subluxations of the shoulder into a post traumatic (traumatic) and an idiopathic (atraumatic) group seems well founded.

The term dislocation is questionable though a true dislocation with no contact between the articular surfaces may occur. "subluxation" with articular contact partially maintained is not unusual. The term "instability" covers the various alternative from slight incongruency to complete dislocation and has therefore been suggested as a more suitable term (DePalma 1973).

Four of the cases in the present series can be classified as instability of the idiopathic type. The aetiology in the case with the football trauma is a little uncertain. The trauma seems significant, but a posterior dislocation which reduces spontaneously must be due to an inherent tendency to instability. It therefore seems reasonable to assume idiopathic instability also in this case.

Several operations have been designed for cases where the symptoms indicate surgical intervention. Such operations are soft tissue operations (Sjovall 1944, Ekman 1948, Severin 1954, Boyd & Sisk 1972, English & Macnab 1974, Lindholm 1974), skeletal operations such as a posterior bone graft (Asplund 1942, Hendenach 1947, Fried 1949, Lindholm 1974) or an osteotomy of the glenoid cavity (Scott 1967, English & Macnab 1974) and combined procedures (Dumon 1967, McLaughlin 1962, DePalma 1973). In the present series a combined procedure with a posterior bone graft and a raphe of the infraspinatus tendon or posterior capsule was

MATERIALS AND METHOD

Specimen material

Fourteen lumbar spines from subjects aged between 18 and 73 years were removed during routine necropsies. The material was collected from cadavers in whom there was no evidence of disease. The spines were dissected into joints consisting of two vertebrae and the intervening disc. Of the joints tested, five were L5-S1, six were L4-L5, four were L3-L4 and three were L2-L3. Table 1 gives details of the specimens tested.

Experimental method

Each joint was stripped of the excess fat and muscles, but the ligaments and muscles joining the vertebrae were not disturbed. The joint was then mounted in surgical cement (caststone) and wrapped in polythene to avoid dehydration. During mounting care was taken to ensure that the plane midway through the intervertebral disc

was parallel to the end-plates of the containers holding the upper and lower vertebrae. This method of mounting helps to ensure that no shear components act on the disc, and so the neural arch is not subjected to backward bending when the subsequent compressive tests are carried out.

Caststone is a stiff material which deforms very little under the forces applied during these tests. When hardening it is also exothermic and a stream of cold air was directed onto the specimen during this stage to avoid any damage from the heat generated.

In life the intervertebral joints are subjected to varying compressive and shear forces. In these experiments, however, only a pure compressive force was applied to the joint. This is not an unphysiological situation since mathematical analysis of forces acting on the lumbar vertebrae shows that the shear force can be easily counteracted by the muscle attachments to the spinous process (Hutton et al 1977, Cyron 1977).

The compressive tests were carried out using a servo-controlled hydraulic testing machine. The upper cross head of the machine incorporated a

Table 1 The details of the results obtained

Table 1

Specimen number	Age	Sex	Intervertebral level	Stiffness of the intact joint kN/cm	Stiffness after neural arch fracture kN/cm
	18	F	L3-L4	56.7	56.7
	18	F	L5-S1	27.5	27.5
	26	M	L5-S1	23.6	23.6
	38	M	L3-L4	30.7	30.7
	38	M	L5-S1	21.4	21.4
	44	M	L5-S1	18.8	18.8
	44	M	L4-L5	29.8	29.8
	44	M	L3-L4	27.5	27.5
	44	M	L5-S1	37.3	37.3
	59	F	L3-L4	18.8	18.8

Table 2

Specimen number	Age	Sex	Intervertebral level	Stiffness of the intact joint kN/cm	Stiffness after neural arch fracture kN/cm
	18	M	L2-L3	34.9	18.4
	18	M	L4-L5	37.0	27.4
	19	M	L4-L5	29.0	24.7
	37	M	L4-L5	26.1	19.6
	44	M	L2-L3	32.7	27.5
	44	M	L4-L5	30.7	21.9
	46	F	L4-L5	26.0	19.6

SPONDYLOLYSIS

The Role of the Posterior Elements in Resisting the Intervertebral Compressive Force

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Compressive tests were carried out on cadaveric lumbar intervertebral joints, before and after the neural arch was fractured. The results show that although the neural arch can play some part in resisting the intervertebral compressive force, there is no bony contact between the downward projecting tips of the inferior articular processes and the laminae of the vertebra below.

Key words: spondylolysis, neural arch, lumbar vertebrae, intervertebral joint.

Accepted 11 iv 78

The neural arch of a vertebra articulates with adjacent vertebrae through the apophyseal joints. The inferior articular processes hang down from the junction of the pedicles with the neural laminae and, through the articulation, resist forward shear forces acting on the intervertebral joint. The mechanics of this passive resistance is complicated by the muscles attached to the neural arch. These muscles have a net bracing effect by pulling down on the neural arch and countering any tendency to forward displacement of an upper vertebra on the one below (Cyron 1977, Hutton *et al* 1977).

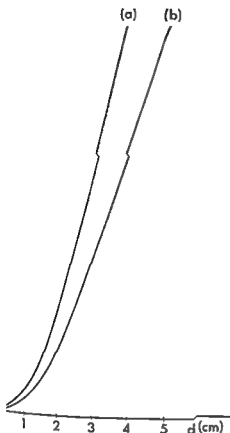
The neural arch is clearly subjected to mechanical stress during everyday activities and a fracture of the laminae across the *partes interarticulares* occurs in about 1 in 20 of the population (Newman 1963, Wiltse *et al* 1975). This type of fracture, called spondylolysis, is often followed by spondylolisthesis, a forward slip of a vertebra on the one below. These conditions are most common at the lumbo-sacral level.

The mechanics of spondylolysis as ex-

plained above, ascribes the stress on the neural arch as solely due to forces perpendicular to the inferior articular facets acting with muscle forces to produce a crucial stress. This explanation does not allow the neural arch to take any part in resisting the compressive force acting on the intervertebral joint, in that the facets glide over each other and in no important way do the tips of the inferior articular processes come into contact with the neural laminae of the vertebra below. There is an alternative theory.

It is suggested that, due to lumbar lordosis, the neural arch of L5 lies in a pincer-like gap between the downward projecting tips of the inferior articular processes of L4 and the upward projecting tips of the superior articular processes of the sacrum. In this theory the compressive force transmitted by the intervertebral joints is resisted mainly by the neural arch of L5 (Nathan 1959).

This paper describes experimental work carried out to quantify the role of the neural arch in resisting intervertebral compressive forces.



3 Typical result showing the force/displacement characteristics of a lumbar intervertebral joint in group 2. In this group the stiffness is decreased after the neural arch had been cut.

LTS

Experimental results are summarised in Table 1.

Intact joints were tested to a maximum compressive load of about 5 kN. After about 1 kN the graphs became relatively linear up to the maximum load and the slope of this linear portion of the graph was measured. The slope of the graph represents the compressive stiffness of the joint (or to be more precise the compressive stiffness of the intervertebral disc plus two vertebrae embedded in the disc).

The results fall into two groups as illustrated by Figures 2 and 3. In the first group, consisting of eleven joints, the results show some residual deformation between graphs (a) and (b) (Figure 2), although the slope of the main portion of the graphs is the same. In the second group, consisting of seven joints, there is a combination of residual deformation and a change in stiffness. Graph (b) in Figure 3 illustrates a result for a joint which is less stiff after the neural arch has been cut.

The stiffness of the intact joints varied between 18.8 kN/cm (L5-S1, specimen 53) and 71.1 kN/cm (L2-L3, specimen 22). The stiffness will depend, *inter alia*, on the thickness of the intervertebral disc (L2-L3 is usually thinner than L5-S1). However, even the highest value of stiffness does not represent the value which would be obtained at very high loads (7–9 kN in flexed posture) when the disc is highly compressed and the end plates of the vertebral bodies are brought closer to each other. In other words, the stiffness of the joint varies with the compressive load, although in the range of loads in these experiments there is a long linear portion.

As to intervertebral level, all of the L5-S1 joints tested fall into group 1 and five out of six L4-L5 joints fall into group 2. There is no clear variation with age or sex.

For four subjects it was possible to test joints at two levels (Table 1) and in every case both joints for each subject fell into the same group (three in group 1 and one in group 2).

DISCUSSION

The maximum value of stiffness recorded in these tests was 71.1 kN/cm. Let us compare this value with the calculated value for the compressive stiffness of the neural arch, when subjected to a force along the line of the neural lamina.

Although the neural lamina is an irregularly shaped structure to provide an approximate

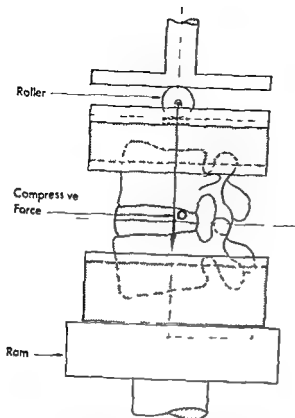


Figure 1 The arrangement of the apparatus for applying a pure compressive force (F_c) to a lumbar intervertebral joint

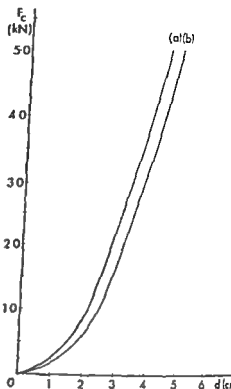


Figure 2 Typical result showing the deformation characteristics of a lumbar intervertebral joint in group 1. In this group stiffness remained the same after the neural arch had been cut

load cell while the base unit held a hydraulic actuator and a displacement transducer.

The following two experiments were then performed.

Experiment 1

The force/deformation characteristics of the intervertebral joint when subjected to a force perpendicular to the plane midway through the disc were determined. This was achieved by applying forces of known magnitude and direction to the joint through a roller (Figure 1). The roller was free to rotate but its axis was fixed. It was placed at the top of the upper container with its centre lying on the line between the point of application of the force and the centre of rotation of the joint. The position of the roller was located by trial and error, a small compressive force (up to 50 N) was applied at each position until it did not cause any tilting of the upper vertebra. The outputs from the load cell and displacement transducer were fed to the X-Y plotter which

plotted the magnitude of the applied compressive force F and the corresponding vertical displacement d (Figures 2 and 3 graphs (a)).

Experiment 2

The neural arch on the upper vertebra was cut with a chisel through the *partes interarticularis* and Experiment 1 was repeated, giving force/deformation characteristics of the intervertebral joint without any contribution from the neural arch (Figures 2 and 3 graphs (b)). It should be noted that the joint was loaded slowly and allowed to recover before the second experiment. By doing so the amount of residual deformation, after the first experiment was kept to a minimum.

After the tests the discs were examined macroscopically for the degree of degeneration. Only results for normal discs and those in which the lack of a clear boundary between the annulus fibrosus and the nucleus pulposus was the only evidence of degeneration were collected.

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tion of its stiffness we can assume it to be a tube of cross-sectional area twice that of each pars interarticularis (A force acting along the neural laminae would also produce shear across the partes interarticulares although we will neglect this for a first approximation)

The cross-sectional area at the partes interarticulares is about 1.5 cm^2 , considering both partes (Cyron & Hutton submitted for publication). The length from the tip of the inferior process to the base of the pedicle is about 2 cm , and the modulus of elasticity of cortical bone, when subjected to compression, has not been found to be less than 300 kN/cm^2 (Evans 1973), therefore the stiffness of the neural laminae is at least 225 kN/cm [$(300 \times 1.5/2)$]. Now the greatest change in stiffness of a joint after cutting the neural arch is 16.5 kN/cm ($34.9 - 18.4$, specimen 35) and this value is over ten times lower than the lowest approximation for the stiffness of the neural laminae. The suggestion that the compressive force on the L5-S1 joint is transmitted for the most part through the neural arch is not supported by our results.

It could still be argued that the pincer-like process may be due to rubbing on the upper and lower surfaces of the L5 neural laminae. This would require the neural laminae to be in close proximity to the tips of the inferior and superior processes of adjacent vertebrae. Under the maximum load in these experiments it would be expected that contact would be made and the graphs would change in slope when the stiff neural arch came to bear. This did not occur in any of our joints although our sample may have been too small.

However, it is possible that under long periods of sustained activity the intervertebral disc may creep and thus narrow, bringing adjacent neural arches closer together. This would suggest that a narrowing of the disc, as may occur in disc prolapse, would correlate with an increase in spondylolysis. There is no evidence to date of this.

In hyperextension the centre of rotation of the intervertebral joint lies in the anterior half of the disc and it is possible that contact

between the tips of the inferior articular process of L4 and the neural laminae of L5 could be made before the spinous process came to bear. If heavy weights were then carried while in this posture the intervertebral disc may narrow and allow the compressive force to be transmitted through the neural arches. This, however, is not likely to be a common cause for spondylolysis when we consider the high incidence of pars interarticularis defects in soldiers walking in the partially flexed posture with a pack on their back (Newman 1963). In addition the neural arch has been shown to be vulnerable to a cyclic force applied to the inferior articular facets (Cyron & Hutton 1978) and mechanical fatigue seems the most common mode of failure.

The question remains why do some of the joints decrease in stiffness after the neural arch has been cut? Consider the magnitude of the change in stiffness for group 2, the values recorded are compatible with the stiffness of soft tissue, the capsular ligaments offer resistance to tension and the inter spinous ligament resistance to compression. This may be an individual variation, specimen 35 shows the same characteristics at two levels.

Conclusion

The results of these experiments suggest that, although the posterior elements can transmit compressive force across the intervertebral joint, there is no bony contact between the downward projecting tips of the inferior articular processes and the laminae of the vertebrae below. This mechanism is therefore not the usual factor in the aetiology of spondylolysis.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of the National Fund for Research into Crippling Diseases and the help of Dr H J Harris, Pathology Laboratory, Stoke Mandeville Hospital, Aylesbury, Bucks, who advised on some aspects of the work, and Mr R F Dickenson who gave advice on the mechanical properties of bone.



Figure 1 The different kinds of underside lesions. Both sides of each meniscus are shown with the anterior part upwards. The undersides are to the right. Marks from Martin's forceps occur in the frontal part of the menisci.

lesions and in two lateral menisci.

Figure 1 shows that the posterior part of the underside of the meniscus is completely crushed. This type of lesion was found in 10 menisci: all medial.

Let handle lesions and 23 peripheral lesions, five with a transverse rupture.)

Figure 1 shows the different kinds of underside lesions. A and B lesions were found in 8 patients with a mean age of 40.1 years.

C lesions in 8 patients, mean age 32.6 years.

D lesions in 10 patients, mean age 32.6 years.

Patients with underside lesions were distributed more equally in the anterior and posterior parts of the meniscus (Figure 2) than patients

UNDERSIDE LESIONS OF THE MENISCUS

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A total of 180 meniscectomies were performed with special attention to lesions located only on the underside of the meniscus. Thirty-six lesions (20 per cent) were found with this location, all in the posterior part of the meniscus. Half of these were atypical horizontal cleavage lesions.

The clinical features of these lesions were compared with those of meniscal lesions and no differences could be demonstrated. The subjective results after meniscectomy for 35 underside lesions were 94 per cent good or excellent after an average follow-up period of 22.3 months.

Meniscectomy is the treatment of choice for these lesions. It is emphasized that careful examination of the underside of the meniscus is necessary if a patient presents a clinical picture of meniscal lesion and no other lesion can be found.

Key words: knee joint injury, meniscus lesions, semilunar cartilage, pathology, trauma, knee joint.

Accepted 21.11.78

The anatomy of the knee makes it difficult to recognize lesions in the posterior part of the meniscus (Henderson 1930, Platt 1930, Slocum & Moore 1943, Palmer 1949, Lescoeur 1969, Smilhe 1975).

Underside lesions are always found in the posterior segment of the meniscus and are difficult to diagnose. They are distinguished from other lesions by not penetrating the upper surface of the meniscal substance.

It is not known whether the symptomatology of these lesions is different from other lesions. Underside lesions are not given much attention in the literature and this investigation was undertaken to clarify the incidence of underside lesions and to compare their symptoms with those in other lesions of the meniscus.

PATIENTS AND METHODS

The material comprises 180 meniscal lesions in 172 patients (63 women, 109 men) operated upon

in a 3 year period. All the meniscectomies were performed with special attention to underside lesions. The diagnosis was made by examination of the underside of the meniscus with a nerve hook. If other lesions were found in the meniscus, the patient was excluded from the underside lesion group. This group was compared with the rest of the patients with other kinds of meniscal lesions. The patients with underside lesions were examined after a period of 8 months to 3½ years and the results were analysed.

RESULTS AND FINDINGS

Thirty-six underside lesions were diagnosed among 180 meniscectomies. 30 of these lesions (83 per cent) were in the medial meniscus, and 14 (39 per cent) were found in women.

In 144 ordinary lesions, 97 (67 per cent) were in the medial meniscus, and 65 (45 per cent) were found in women. (There were 10 lesions of both the anterior and the posterior horn, 45 posterior horn, 10 anterior horn

Table 2 Objective symptoms

	Underside lesions	Other lesions
Direct tenderness at the line of the joint	34/36	129/144
Rotational tenderness at the line of the joint	26/36	86/144
Clicking or snapping felt or heard during examination	12/36	92/144
Limitation of extension	9/36	44/144
No findings at the time of operation	0/36	7/144

Table 3 Duration of symptoms before operation

	Underside lesions	Other lesions
Less than 1 month	6/36	35/144
1 month to 1 year	24/36	71/144
More than 1 year	6/36	38/144

Table 4 Percentage of the various pathological findings in the knees (at meniscectomy)

	36 Underside lesions	144 Other lesions
Lesions of the ligaments	16	14
Osteochondritis or damaged condylar cartilage	19	23
Osteoarthritis	11	14
Chondromalacia of patella	16	14
Synovial effusion or irritation	44	47
Loose bodies	8	8
	2	-

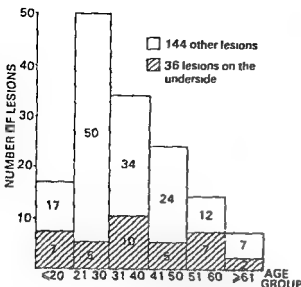


Figure 2 Age distribution

Forty-seven per cent of the patients over 50 years of age had underside lesions.

The symptoms are shown in Tables 1 and 2. Patients with underside lesions more often presented with periodical symptoms. The period of time before surgery is shown in Table 3. The percentage of other abnormal findings (Table 4) in the knees is the same in both groups except as regards meniscal cysts, these occurred two to three times more often in patients with underside lesions.

The subjective results are shown in Table 5. Fifty-seven per cent (20) had no complaints and were able to perform all previous activities even sport. In 37 per cent (13) the results were good. The patients felt discomfort after hard or long lasting physical strain or during changes in the weather. Six

per cent (2) of the patients did not notice an improvement after meniscectomy.

One of these patients, a 49-year-old male had arthrosis in the knee and a Benjamin osteotomy was performed later. The other patient was a 29-year-old male in whom a large osteochondritic defect was found on the femoral condyle. Later a hemiarthroplasty was performed.

From Table 5 it can be seen that six of the patients with residual discomfort had either patellar chondromalacia or disease in the condylar cartilage. Five patients with the same findings obtained excellent subjective results and so did seven patients with either arthrosis or lesions of the ligaments. Of the six patients with a second meniscectomy on the other side of the knee, three had sustained a new trauma.

DISCUSSION

Noble (1977) found, in 200 autopsies, nearly 20 per cent with meniscal lesions. The lesions were all horizontal cleavages, which probably had not given rise to any symptoms. Smulie (1977) states that cleavage lesions in general are more frequent now than previously and they occur in an older age group. He demonstrates that some of these lesions are the result of degenerative changes in the substance of the meniscus and that they will often start on the inferior surface of the meniscus.

Careful examination of the inferior surface

Table 1 Subjective symptoms

	Underside lesions	Other lesions
Locking	14/36	64/144
Intermittent symptoms pains, click, giving way	21/36	67/144
Constant pains	9/36	61/144
Constant pains with periods of worsening	6/36	16/144

FORMATION OF NEW MENISCI AFTER POLYCENTRIC KNEE ARTHROPLASTY

Report of Four Cases, One with a Bucket Handle Tear

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This paper presents four patients with polycentric artificial knee joints in whom reoperation revealed new menisci interposed between the artificial

and the reoperations were performed because of trauma in one patient because of femoro-patellar problems in one knee and for conversion of a hemi arthroplasty to an arthroplasty including all the compartments of the knee joint in two patients.

Key words Marmor knee, meniscus tear, polycentric knee arthroplasty, meniscus regeneration, St Georg knee

Accepted 9 v 78

degeneration, at least to some extent, of the new meniscus after surgical removal is an accepted phenomenon (Smillie 1963, 1974). Excision of an injured meniscus from an otherwise normal knee joint will generally be subtotal. A capsular brim will be left, from which the regeneration can proceed. In knees subjected to polycentric, unicondylar arthroplasty because of degenerative or rheumatoid arthritis, the menisci are often absent at the time of operation. If they are still present they are radically excised to allow the tibial prosthetic component to be put into place.

Since June 1976 we have reoperated on our patients who had undergone a polycentric knee arthroplasty. Two of the arthroplasties were of the St Georg Schlitten" type (Engelbrecht 1971) and two of the Marmor type (Marmor 1973). The reasons for the reoperations were traumatic injuries to the joints or conversion of a

uncompartment to a duocompartment arthroplasty. All four knees showed meniscus-like formations between the artificial surfaces. One of the menisci had a bucket handle tear. This meniscus was excised and could thus be examined histologically.

CASE REPORTS

Case 1 DA, a 55 year-old woman had had severe rheumatoid arthritis since 1961, with multiple involvement of the joints. She had had no steroid therapy. Her left knee was unstable, with poor function, and caused severe pain. Because of this she was operated on in December 1975. At operation a fairly inactive synovitis and heavy destruction of the joint surfaces were found, both menisci were completely eroded. Marmor arthroplasty including both compartments was performed. She quickly gained good mobility of the knee, was able to walk well, and had no swelling. However there was a femoro-patellar joint

Table 5 Subjective results after meniscectomy of 35 underside lesions The main findings during the operation and the later operations on the knees are shown in each group

		Lesions of cruciate ligaments	Chondromal- acia of patella	Osteochondritis or cartilage damage	Arthrosis	Later operations on the knee
Excellent	20 (57 per cent)	4	2	3	3 (1 severe)	3 (2 meniscectomies 1 Hauser operation)
Good	13 (37 per cent)	1	3	3		4 (meniscectomies, one also synovectomy)
Unchanged	2 (6 per cent)	1	1	1	1	2 (1 Benjamin operatio 1 hemialloplasty)

of the meniscus with a nerve hook revealed that one fifth of the meniscal lesions were located here, always in the posterior part of the meniscus. Half of these lesions were obviously atypical horizontal cleavage lesions and the other half might have developed from similar lesions. The symptoms in patients with underside lesions were the same as the symptoms in patients with other well known types of meniscal lesions. After meniscectomy for underside lesions, 94 per cent achieved excellent or good results. This is in agreement with the results from the literature, i.e. good or excellent results in 65 to 100 per cent of the cases (Saugmann-Jensen 1963). The results of this follow-up must be taken with reservation as the observation period is only 22.3 months on an average.

Underside lesions may be symptomless, but a patient with a clinical picture of meniscal lesion must be carefully examined for underside lesions, if no other lesions are found in the meniscus. In such cases underside lesions are an indication for removal of the meniscus. Whether the examination for

underside lesions can be performed as reliably by arthroscopy as by arthrotomy has not yet been clarified.

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Methods Sections were stained according to van Gieson and with haematoxylin and eosin. The light microscopical findings were those of a fibrocartilage built up of cartilage cells with a scanty matrix surrounded by a dense connective tissue with abundant collagen in parallel, wavy bundles (Figure 3). The structure was covered by a loose synovial membrane (Figure 4) and the morphology was thus almost indistinguishable from a normal meniscus.

Case 3 P.P., a 70 year old man, sustained in the 1960's an open tibial fracture of the right leg, which had healed after several operations. Because of an idiopathic osteoarthritis in the right knee, a demi arthroplasty including the lateral compartment, was performed in March 1974. A St Georg "Schlitten" prosthesis was used. Unfortunately a slight overcorrection into varus position was made, and pain developed from the medial compartment of the joint. The arthroplasty was therefore complemented with a Marmor prosthesis in the medial compartment 3 years later. A meniscus-like formation was found between the surfaces of the St Georg prosthesis, which seemed to fit well and to be quite firmly in position. The meniscus showed no signs of injury and was left in place. The function of the knee after the additional arthroplasty was excellent.

Case 4 B.A., a 50-year-old man had had rheumatoid arthritis since 1969. Multiple joint involvement had resulted in general functional impairment, but he was still working in a workshop. Because of severe pain and derangement of the right knee, a polycentric unicondylar arthroplasty, including both compartments of the knee joint, was carried out in 1976. A Marmor prosthesis was used. Postoperatively the patient was completely free of pain and the knee function was excellent. Six months later a Charnley arthroplasty was performed in the right hip, and the result of this operation with regard to function and freedom from pain was also excellent. Eighteen months after the knee operation a traumatic distortion of the right arthroplastic knee occurred and there were clinical signs of a loose body (bone cement)

An arthrotomy was therefore carried out and the loose body removed. At the arthrotomy it was noted that new menisci had formed between the artificial joint surfaces. They appeared healthy with no signs of injury, and were left in place. Postoperatively, good joint function was regained.

COMMENTS

The finding of new menisci between the artificial surfaces in polycentric knee arthroplasties indicates a strong capacity for regeneration from the fibrous capsule.

The healthy appearance of the meniscus in all but one of the four cases reported here hopefully indicates that the function of the artificial knee resembles that of the normal knee joint. In polycentric artificial knees with unicondylar components, such as the Marmor or the St Georg "Schlitten" prosthesis, the possibility of an injury to a newly formed meniscus should be kept in mind if, after a period of good function, signs of mechanical trouble appear and there are no roentgenological indications of prosthetic problems.

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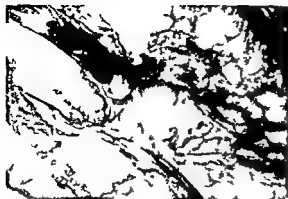


Figure 1 Anterior view of the arthrotomized knee joint showing the St. Georg prosthesis and the bucket handle tear of the new meniscus

Figure 2 The excised meniscus

roentgenologically conflict was found between the patella and the lateral femoral prosthesis. An arthrotomy was therefore carried out 6 months after the primary operation and a hemipatellolectomy was performed. It was noted that there were meniscus like formations between the joint surfaces in both compartments. The newly formed menisci appeared almost like normal ones. After the reoperation her function was excellent and the knee caused no pain. She has now been followed up for 2 years and in that time has had no trouble with the treated knee.

Case 2 B.M., a 62 year-old woman, sustained an injury to her left knee in 1971 with a depression fracture of the medial tibial condyle. This was treated by open reduction and fixation with screws. Later on an osteotomy had to be performed to compensate for an unacceptable joint position. Increasing pain on weight bearing followed and in 1973 a unicondylar St. Georg prosthesis was inserted in the medial

compartment of the left knee joint. Some stability remained and after a year or two began to have pain in the knee localized over lateral compartment. There was no locking of knee joint. In February 1977 a further operation was performed, at which the knee prosthesis complemented with a Marmor prosthesis in lateral compartment. The first St. Georg prosthesis was found to be sitting firmly in position with no signs of wear. A new meniscus, with bucket handle tear (Figure 1) had formed between the artificial joint surfaces of the St. Georg prosthesis and was excised (Figure 2). Postoperatively the patient quickly gained walking ability and an almost normal range of movement and had hardly any pain in the knee. The excised meniscus was examined histologically.

Histopathology The removed material was fixed in 4 per cent buffered formaldehyde dehydrated and embedded in wax according to routine



Figure 3 Light microscopy of the new meniscus showing a fibrocartilage built up of cartilage cells surrounded by a dense connective tissue with abundant collagen in parallel wavy bundles



Figure 4 A loose synovial membrane covering the structure, the morphology of which was very much like that of a normal meniscus



Figure 1A Antero-posterior roentgenogram, showing abnormal prominence of the fibular head



B In the lateral view, the head of the fibula is seen projecting anteriorly

He presents 43 cases 29 antero-lateral luxations, three postero-medial, one superior luxation and finally 10 cases of subluxation. The latter condition is described as an excessive symptomatic antero-posterior movement without any actual luxation. As is demonstrated in this series antero-lateral luxation is the most frequent type. It was shown that the postero-medial type involves increased risk of nerve damage and that the proximal or superior type is unusual and has not been observed as an isolated lesion but always in connection with a fracture. According to Ogden most antero-lateral luxations arise during participation in sport, specially after violent twisting movements.

The injury may however arise from direct trauma.

The symptoms consist primarily of pain and tenderness in the region of the head of the fibula. There is often an extension defect and the patient is unable to stand on the leg. Diagnosis can usually be made clinically, but an X-ray examination of both knees is required for verification. The lesion can easily be overlooked if the X-ray picture is not optimal. Treatment is simple and as in the case described here consists of closed replacement of the head of the fibula. *End*

with this case suggests that

ISOLATED TRAUMATIC LUXATION OF THE HEAD OF THE FIBULA

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Isolated traumatic luxation of the head of the fibula is a rare lesion. The lesion is discussed against the background of a diagnosed and treated case.

Key words: dislocation, fibula.

Accepted 4:78

Traumatic luxation of the head of the fibula is a rare lesion, seldom reported in Scandinavian medical literature (Christensen 1966, Gudbjerg 1970, Bacieu et al 1974).

In major radiological textbooks the luxation is described briefly (Schinz et al 1952) whereas no reference in the lesion is to be found in ordinary textbooks of surgery.

CASE REPORT

An 18-year-old girl with no previous history of knee injury fell while playing handball. She hit her left knee and felt a "click". On examination the knee was fixed in 140° of flexion due to pain, and a painful swelling was seen on the lateral side of the knee joint. There was no haemarthron or instability of the joint and no sign of peroneus paralysis. X-ray examination of the knee (Figure 1A and 1B) showed an antero-lateral luxation of the head of the fibula but no fracture. A closed reduction was carried out with local analgesia. An audible crack accompanied the

replacement of the bone. X-ray examination showed that the luxation had been reduced. Full mobilization with support was allowed immediately.

X-ray examination 6 months later showed normal conditions (Figure 2A and 2B). The patient was symptom free and the clinical examination normal.

DISCUSSION

The lesion was first described by Nélaton in 1874. In 1925 Lyle collected 36 cases from the medical literature and described two new ones. Of these 36 cases, 20 were antero-lateral luxations, 12 were posterior and 4 superior. More recently further cases have been documented in the literature (Stratford 1959, Harrison & Hundenach 1959, Christensen 1966, Gudbjerg 1970).

Ogden's material from 1974 is the largest.

STABILITY OF THE PROXIMAL TIBIO-FIBULAR JOINT

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University Hospital, Utrecht, The Netherlands

The proximal tibio-fibular joint consists of a joint cavity surrounded by a joint capsule (diarthrosis) forming a rather rigid joint. In patients who complain of pain and instability in the knee, the cause may sometimes be found in laxity of the proximal tibio-fibular joint. In these cases the abnormal movements of the fibular head are palpable and visible and can be demonstrated on X-ray films.

The disease is not well known and is often overlooked. It can be differentiated by palpating the fibular head. In two patients the pain and disability were so severe that fusion of the proximal tibio-fibular joint was undertaken. This treatment seems to have been successful.

Keywords: arthrodeseis, head of fibula, instability, proximal tibio-fibular joint.

Accepted 25 III 78

Stability of the proximal tibio-fibular joint

The proximal tibio-fibular joint consists of articulating surfaces of the upper end of the fibular head and the lateral condyle of the tibia, which are covered with hyaline cartilage. The capsule is reinforced anteriorly and posteriorly by two ligaments. Radiographically the joint space is visible only in oblique projections.

In the orthopaedic and literature, dislocation of the fibular head is mostly described in combination with fracture of the tibia and the history of a traumatic disorders of the knee.

Symptomatology

Recurrent dislocation of the proximal tibio-fibular joint is found sometimes in the history of a traumatic disorder of the knee.

Patients complain of "My knee locks" and "There is a click somewhere in the joint". Diffuse pain, not only in the unstable joint, but sometimes on the medial side of the knee is recorded, suggesting a meniscus lesion. However there is no wasting of the quadriceps and no swelling.

Because this lesion is not found in older patients there seems to be a tendency towards spontaneous improvement.

Signs

Examination of the fibular head is best with the patient in the supine position. The knee is flexed to 90°, with the hip in extension. Especially the biceps femoris muscle is unstable. The fibular head is palpable with thumb and index finger can be moved anteriorly and laterally. On release there is a click to its original position. This can be to the extent of 1 cm. It is clearly visible (Figure 1).

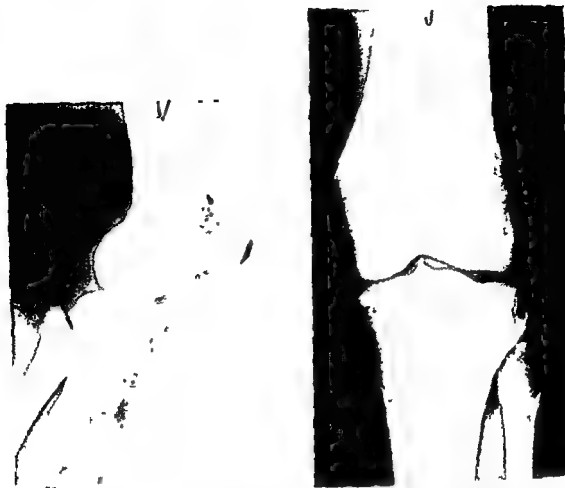


Figure 2A Antero-posterior view, normal position of the head B In the lateral view, normal position

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neural nerve and its branches are kept aside fully. The proximal tibio-fibular joint is freed anteriorly and the joint cartilage moved with small chisels. The next step in the operation is to fix the roughened joint surfaces to each other under compression with two selflapping spongiosa screws. To fill defects in the arthrodese joint, spongiosa chips can be taken from the tibial area through the same incision. A below-knee circular plaster is applied on the 10th operative day after removal of the chisels. This plaster is worn for 5 weeks. Full weight bearing is permitted 8 weeks after the operation.

RESULTS REPORT

In this report six cases have been collected and the data are given in Table 1. One of the cases (case 3) is reported in detail.

Case 3

A girl 14 years old was referred in November 1969 with a 6-month history of weakness in both knees. She experienced pain during sporting activities and she had trouble going upstairs. Four months prior to the onset of knee symptoms, the right knee had suffered a minor injury but she could recall no further trauma.

On examination the girl was of the asthenic type. The knees were not swollen and the mobility was unimpaired. The collateral and cruciate ligaments were intact. Posterior pressure on the fibular head caused it to dislocate more than 1 cm anteriorly (Figure 3).

Analgetics did not relieve the disability. In the course of a few months her knees grew worse preventing her going up and down stairs and attending school.

Because the only abnormality was the instability of the fibular head it was decided to arthrodese the unstable upper tibio-fibular joint. The operation was done in March 1970 on both knees according to the method described pre-

Table 1 Patients with laxity of the proximal tibio-fibular joint. Cases 1-5 have bilateral symptoms, case 6 has unilateral symptoms of traumatic origin.

Age	History	Anamnesis Complaints	Handicap	Treatment
5 years	trauma	click in both knees, pain absent	—	—
17 years	trauma	no symptoms, no pain	no handicap participates in several sports	—
14 years	slight trauma, right knee	bilateral knee troubles, gradually growing worse	unable to go up and down stairs and to take part in sport	arthrodese proximal tibio-fibular joints, complete recovery
15 years	bilateral knee trouble of 2 years duration	giving way of both knees	unable to take part in sport except swimming	arthrodese proximal tibio-fibular joint complete recovery
19 years	bilateral knee troubles of 4 years duration Visited several doctors	click in both knees, no locking	unable to take part in sport (was an enthusiastic sportsman)	—
18 years	2 years previously trauma to left knee with multiple skin wounds, 1 year previously lateral meniscectomy	click in lateral compartment of the left knee	unable to take part in sport	in the past a meniscectomy without relief



Figure 1 Antero lateral dislocation of the fibular head, induced by manual pressure, in a 19-year old boy (case 5)

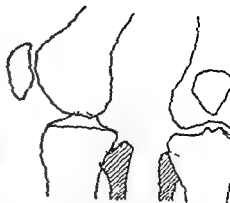
This examination is not painful and can be done in a relaxed patient without any form of anaesthesia

Radiological appearances

The antero-posterior radiographs, in the case of a dislocated tibio-fibular joint, show a lateral dislocation of the fibular head, the lateral radiograph reveals an anterior displacement (Figure 2)

Treatment

The hypermobile tibio-fibular joint occurs with different degrees of laxity. In mild cases the patient is not always aware of the disorder and no treatment needs to be given. In cases giving rise to trouble only during



NORMAL RADIOGRAPHS



DISLOCATED FIBULAR HEAD

Figure 2 Antero-lateral displacement of the fibular head in AP and lateral radiographs

sporting activities, a supportive bandage can be used. Because the symptoms tend to disappear spontaneously, operative treatment is seldom necessary.

However the clinical picture is rather similar to that of a meniscus lesion and sometimes by error a meniscectomy is carried out (case 6). In a few cases the instability may even make stair climbing difficult. In these patients operative treatment should be considered. Operative fusion of the proximal tibio-fibular joint was carried out in two of the patients described.

Surgical technique

In a bloodless extremity, the fibular head is freed through a 7 cm longitudinal lateral incision. After careful preparation the

Nerve and its branches are kept aside **Case 3**

The proximal tibio-fibular joint is anteriorly and the joint cartilage with small chisels. The next step in operation is to fix the roughened joint to each other under compression with selftapping spongiosa screws. To correct defects in the arthrodesed joint, bone chips can be taken from the tibial through the same incision. A below knee plaster is applied on the 10th operative day after removal of the plaster. This plaster is worn for 5 weeks. Weight bearing is permitted 8 weeks after the operation.

REPORT

In this report six cases have been collected. The data are given in Table 1. One of the cases (case 3) is reported in detail.

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superior tibio-fibular joint and described two adolescents suffering from this disorder. The disability in these cases was to such a mild degree that surgery could be avoided. It is evident that the symptoms in acute traumatic dislocation of the proximal tibio-fibular joint catch the attention of the clinicians much more than the rather vague complaints in recurrent (sub)luxation of the joint. This is the reason why this disorder may be easily overlooked and seldom is reported in the literature.

Ogden (1974) studied 43 cases of subluxation and dislocation of the proximal fibula. Six of them had chronic instability (subluxation). They were aged from 8 to 14 years. In his opinion idiopathic subluxation in the young patient should not be treated surgically, as it appears to be a self-limiting condition. He considers that when necessary, resection of the proximal fibula is preferable to arthrodesis of the proximal tibio-fibular joint, in order to preserve the function of the ankle joint.

The cases in this paper have all been observed within a period of 5 years. This suggests that the disorder under discussion is not so rare. Early diagnosis gives an understanding of the dysfunction of the knee and can avoid unnecessary and possibly inappropriate surgery (case 6).

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Provided there had been no previous loss of bone substance at the metatarsophalangeal joint a hallux valgus deformity with or without rigidus did not adversely affect the incidence of union after cone arthrodesis. In his survey ten such toes united without complications. Their preoperative valgus angles between 25 and 48 degrees with an average of 33 degrees.

Movement at the arthrodesis site prior to radiological union

Six arthrodesed toes had to be excluded due to insufficient data. Out of the remaining 7 toes comparative values for the Valgus Angle A were available in 76 and for the Dorsiflexion Angle B in 22 toes.

Out of the 77 toes where one or both of these measurements were available there was evidence that movement had occurred between the proximal phalanx and the first metatarsal in three. In two toes the movement had taken place at a stress fracture of the metatarsal and not at the arthrodesis site. The third patient was the only one where movement was shown to have occurred at the

arthrodesis itself. In this patient no additional wire or staple fixation had been used.

In the other three toes where stabilization had not been used uncomplicated union occurred without evidence of change in the operative position.

In none of the 29 toes examined clinically was there any evidence of a significant rotation deformity of the great toe.

Wire and staple fixation

A wire circle was used for stabilization in 79 toes. This had disrupted due to a fatigue fracture of the metal in the two ununited arthrodeses and in the patient with an ununited stress fracture across the base of the cone (Figure 2B). In the remaining 76 arthrodesed toes the circle was intact.

In no patient did the metal cause any significant symptoms or have to be removed.

Complications

- (1) Stress fracture of the metatarsal occurred in two toes. One patient had a stiff ankle from a previous injury and sustained a

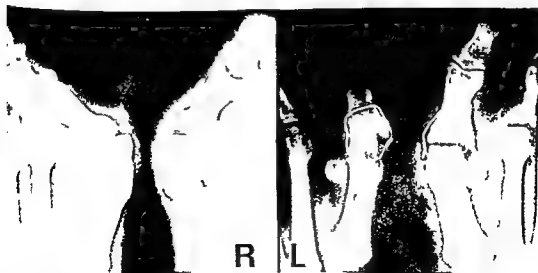


Figure 2 Radiographs showing a stress fracture through the base of the right cone in a patient previously undergone bilateral exostectomies. A Before arthrodesis. B 2 years after arthrodesis. The left side has united.

stress fracture of the first metatarsal neck 3 years after arthrodesis

The second patient sustained a stress fracture through the base of the cone 12 weeks after surgery. Previously she had undergone bilateral exostectomies thus narrowing and weakening the metatarsal heads. Both arthrodeses united, but the stress fracture went on to non-union (Figures 2A and B)

- (2) There was one patient with transient superficial sepsis of the wound. No deep sepsis was encountered. No other complications of the operation itself were noted.

DISCUSSION

In patients who had undergone no previous surgery to the metatarsophalangeal joint, cone arthrodesis resulted in a union rate of 100 per cent. This probably relates to the ideal conditions for arthrodesis that can be achieved with this technique. A perfect driving fit is obtained between the proximal peg and distal cone thus bringing the cancellous surfaces into intimate contact.

These ideal conditions are much more difficult to achieve where bone has been removed at previous surgery. Such a procedure inevitably weakens and narrows the cone available for arthrodesis. Following previous *ple* metatarsal exostectomy two toes failed to unite and one sustained a stress fracture across the base of the cone. However, uncomplicated bony union occurred in four toes after simple exostectomy, four after a previous Mayo procedure and one after a Keller operation. Where previous surgery has resulted in loss of bone substance at the metatarsophalangeal joint, cone arthrodesis is probably the best method of obtaining bony union.

In this retrospective survey clinical assessment of rotation and the comparative values for valgus and dorsiflexion angles were not available in all patients. However, all three criteria were recorded in each of 18 toes and showed no evidence of a change in the

operative position up to the time of bony union. At least one of the two angles was recorded in 59 arthrodesed toes. A change in the operative position at the time of union occurred in only one of these and in this case no additional stabilization had been used.

Although these records are incomplete they can be taken as a strong indication that cone arthrodesis using a wire stabilization technique does maintain the operative position until bone union occurs.

Conclusions

- (1) Cone arthrodesis of the first metatarsophalangeal joint gave a 100 per cent union rate in patients who had not undergone previous surgery to the joint.
- (2) A high incidence of union is achieved by this technique even in patients who have lost bony substance from the joint at previous surgical procedures.
- (3) There is a strong indication that the technique described, using wire stabilization, does maintain the arthrodesis in the position obtained at operation until bony union occurs.

ACKNOWLEDGEMENTS

I am very grateful to the Medical Records Department of the Royal National Orthopaedic Hospital for their help in following up these patients, and to the Photographic Department of the Institute of Orthopaedics for the illustrations.

In particular I would like to thank Mr J N Wilson for his guidance and encouragement in the preparation of this paper.

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PROCEEDINGS OF THE NORWEGIAN ORTHOPAEDIC ASSOCIATION

EDITOR ARNT JAKOBSEN

Oslo, September 17th, 1977

TRAUMATIC DISLOCATION OF THE HIP JOINT

*Arnt Reigstad
Ullevål Hospital, Oslo*

In the period 1960-1976, 57 posterior dislocations of the hip joint were treated in Ullevål Hospital, Surgical Department 2. The mean age was 31 years, half of the patients were between 15 and 30 years of age, and three-quarters were males.

Traffic accidents caused 66 per cent, and skiing accidents 9 per cent of the dislocations. Twenty-five per cent of the patients suffered from other serious injuries, and two of the patients died.

Thirty-three per cent had a small, and 11 per cent a large fracture of the acetabulum, 9 per cent had a fracture of the head or shaft of the femur, and compression of the sciatic nerve was seen in 5 per cent.

Seventy-five per cent of the dislocations were reduced within 5 hours after the injury. Eighteen per cent had open reduction and/or fixation of the fracture.

During the observation time, 11 per cent of the patients developed traumatic arthritis, all having had fractures of the acetabulum, and avascular necrosis of the head of the femur was seen in 5 per cent.

FIBROSARCOMA IN THE SHOULDER REGION

*Scenon M. Syversen
Ullevål Hospital, Oslo*

A 33-year-old man had suffered for a period of 6 years from shoulder pain, and had gradually

tion showed fibrosarcoma.

The patient died 6 months later from pulmonary metastases.

Oslo, October 27th-29th, 1977

TOTAL PROSTHESIS OF THE KNEE JOINT

*Cato Hellum
Kronprinsesse Marthas Institutt, Oslo*

Since the year 1971 the Guepar prosthesis has been inserted into 40 knees. Thirty-five had rheumatoid arthritis, nine knees had been operated on previously, and eight had ankylosis of the contralateral knee.

Technique and aftertreatment (*Acta orthop scand* 47, 579, 1976)

The results were good in 29 cases. There was occasional pain or swelling in three cases and eight were classified as poor. Of the eight poor results in one the stem perforated the femur and there was very limited mobility, one had infection and almost complete ankylosis, and two had infection and prosthesis removal. Two other patients with infection were able to walk around during antibiotic treatment with only slight symptoms, but a flare-up occurred if medication was stopped. In two cases loosening of the prosthesis occurred.

PROSTHESES OF THE KNEE JOINT

*Leif Egil Nygaard
Central County Hospital, Fredrikstad*

The results in 17 cases of Guepar total prosthesis, and in 10 cases of Marmor modular prosthesis, are reported. In one case infection occurred.

The total prosthesis is preferred if there is gross destruction, instability and poor mobility. The condylar prosthesis is used in knees with less destruction and greater mobility. In the latter type better stability can be gained, but the range of motion remains unchanged.

KNEE PROSTHESES IN RHEUMATOID ARTHRITIS

J Teigland

Oslo Sanitetsforening Rheumatism Hospital, Oslo

A follow-up examination in 1977 of 31 McIntosh knee prostheses, inserted in the period from 1968 to 1973, revealed that in 16 of these joints the prosthesis was still in use without any particular subjective inconvenience. All had to a greater or lesser extent become embedded in the tibia.

In the same period 21 Stuer prostheses were inserted, of which 19 still are working well. Two have been removed, one because of infection and one on account of severe skin necrosis.

From 1973 to 1977, 71 Guepar prostheses have been inserted. Sixty-five are working well, one became infected, one loosened and was refixed, and one required re-operation because of pronounced outward rotation of the tibia and patellar dislocation.

Since 1974 3 Schlitten and 13 Marmor prostheses have been inserted. In one case the prosthesis became embedded in the tibia, and had to be replaced with a Guepar prosthesis. The remaining have so far been satisfactory.

POLYGLYCOLIC ACID (DEXON®) INTRACUTANEOUS SUTURE IN

cutaneous skin closure with absorbable sutures, where stitches do not have to be removed, obviously has some advantages in paediatric surgery. It has been found, however, that intracutaneous closure with Dexon® has given hypertrophic scars.

In a comparative study in 37 patients, age range 4-13 years, half of the wound, or one of the wounds in bilateral operations, was closed with conventional interrupted skin sutures (Supramid®), the other half with intracutaneous suture (Dexon®), 50 wounds with each technique.

Inflammatory reactions 14 days after operation were least common after intracutaneous suture. At follow-up, mean 14 months after operation, hypertrophic scar formation was found in 71 instances, but no significant difference was found between the two techniques. The scars tended to be broader, but the total cosmetic results to some extent favoured Dexon® intracutaneous suture.

TENODESIS FOR CLAW-HAND

Olav Hystel

Kronprinsesse Marthas Institutt, Oslo

Seven patients operated for claw hand *ad modum* Parkes have been followed up. The primary cause of the lesions was injury of the ulnar and median nerves.

The grip function of the hand in which the metacarpo-phalangeal joints have a key position, was evaluated. Results were good or fair in six patients. One patient who had a poor result showed considerably reduced finger extension function.

It is concluded that in Parkes' tenodesis operation for claw hand, good preoperative function of flexion and extension muscles is mandatory.

THE ROLE OF THE CORACO-ACROMIAL LIGAMENT IN SHOULDER DISORDERS

A Vebostad

County Hospital, Harstad

The author has made some clinical and per-operative observations indicating that the rotator cuff in some cases of painful arc syndrome impinges on the coraco-acromial ligament as well as on the acromion. Support for this observation is found in the literature. The ligament, therefore, should be sectioned in chronic shoulder disorders, either alone, or most often as part of the operative procedure.

Seven out of 21 patients referred for chronic painful arc syndrome, who showed tenderness of the coracoid process, had the ligament sectioned as the only treatment. Two patients were relieved of the pain immediately and completely, four were relieved of the discomfort which was localized to the coracoid process although the laterally localized pain continued, and in one patient no effect was observed.

SURGICAL TREATMENT OF PARTIAL ACHILLES TENDON RUPTURE

Tor Finn Denstad & Asbjørn Roaas
Martina Hansens Hospital, Sandvika

Partial Achilles tendon ruptures are not uncommon in physically active individuals, in particular middle- and long-distance runners.

Fifty-eight partial tendon ruptures in 54 patients have been treated, during the period 1970-1976, by excision of pathological tissue.

side-to-side closure of the tendon defect and immediate postoperative exercises directed by a physiotherapist.

40 patients returned a questionnaire. The result was excellent or good in 52 instances in three of these after re-operation. One patient had died from unrelated causes. The remaining five were improved, but the observation time was short.

SUPRASCAPULAR NERVE COMPRESSION FOLLOWING FRACTURE OF THE SCAPULA

Ladny Fjeld Solheim & Asbjørn Roaas
Martina Hansens Hospital, Sandvika

Residual disability following a fracture of the scapula might be due to a lesion of the suprascapular nerve where it passes through the suprascapular notch.

A 32-year-old man with a fracture of the notch, and lesion of the suprascapular nerve is reported. A nerve decompression operation including a wide resection of the notch, was performed 20 months after the injury, with relief of pain.

The value of X-ray examination, using projections visualizing the suprascapular notch, and a local anesthetic block at the notch in order to diagnose lesion of the nerve is emphasized.

FRACTURE OF THE TALUS IN CHILDREN

Helge Fjermøros
Central Hospital in Kristiansand, Kristiansand

Fractures of the collum tali are of special interest, because this type of fracture often leads to necrosis of the trochlea, and/or development of osteoarthritis in the talo-crural or the subtalar joints. This fracture is only mentioned in the literature 15–20 times in children under 15 years of age.

Two cases of severe fracture-dislocation of the collum tali in children, aged 10 and 13 years, were treated at our hospital with open reduction, and treated with non-weight-bearing with the use of crutches for one-and-a-half and one year, respectively. The fractures have healed, and the children have no discomfort at all, 3–4 years later. Radiological examination showed for a time all the signs of necrosis, but later re-vascularisation took place. The shape of the talus is fairly well preserved.

This good result is attributed to the very long period of non-weight bearing and this is recommended in similar cases.

ARE "IMPACTED" FRACTURES OF THE NECK OF THE FEMUR REALLY IMPACTED?

Ulf Slungaard
Aker Hospital, Oslo

During a 5-year period ending June 1977, 117 patients with so-called impacted fractures of the neck of the femur were admitted to Aker Hospital. Fifty-eight were treated with primary osteofixation, while 59 were treated conservatively with non-weight-bearing, most often because of minimal dislocation on lateral X rays.

Out of 51 of the latter who were followed up, 12 dislocated without a new trauma after an interval of a few days up to 4–5 weeks, i.e., disimpaction occurred in 20 per cent.

The term "impacted" often seems to be a misnomer, and it is proposed that these fractures be called, e.g., fractures of the first degree, or fractures with minimal or moderate dislocation.

OSTEOMYELITIS FOLLOWING FRACTURE SURGERY

Rolf Hagen
Martina Hansens Hospital, Sandvika

During the period 1967–1975 a total of 62 patients with 63 previously operated fractures were treated for osteomyelitis after osteosynthesis. The lower extremities had been fractured in 89 per cent of the cases, and 54 per cent were closed injuries. About half of the patients had been operated within 24 hours after injury, 30 with insertion of plates and 25 with insertion of intramedullary nails or pins, 51 per cent revealed postoperative instability.

The treatment consisted mainly of sequestrectomies and saucerizations, supported by 3–12 months Lincomycin* medication. In 30 was used, perfusing the wound with a Lincomycin* solution.

The average follow-up was 6.5 years, and the result was judged as good in 74 per cent, fair in 8 per cent, and poor in 18 per cent. The amputation rate was 14 per cent.

Stable implants should not be removed before clinical consolidation has been achieved, while rigid internal or external Hoffmann fixation. Autologous cancellous bone-grafting of a purulent pseudarthrosis should be postponed until infection has subsided or practically disappeared.

musculo-skeletal system in 500 transplantations are reported.

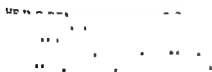
Two were treated with a total prosthesis, and 2 with arthrodesis of the hip joint, one had intramedullary osteotomy for epiphyseolysis of the end of the femur, and two had calcaneal tendon repair. The remaining patients were treated with minor or partial weight-bearing and started on active exercises.

STRUCTURAL MODEL OF THE HUMAN SPINE

by A. Ashton Miller

Minde Orthopaedic Hospital, Oslo

A two-dimensional structural model of the human ligamentous spine with a minimum set of trunk muscles required for equilibrium was prepared. Input data for segmental flexibility and mass distribution were taken from the published data of others. The results showed the distribution of muscle and reaction forces, as well as deflections, along the length of the spine (T-L5). Maximum values for the muscle and axial compressive forces occurred at the thoracolumbar junction in the spine with normal APometry.



In 1962, 52,500 chest roentgenograms (minifilms) were taken in the county of Finnmark during a survey for tuberculosis. This represented 52 per cent of the population over 6 years of age. Until now 21,130 minifilms have been examined. Of these 6,200 are children 7-18 years of age, 2,300 collected from traditional Lapp communities and 3,900 from towns along the coast where the population is predominantly non-Lappish.

Evidence of scoliosis ($> 10^\circ$ Cobb) was found in 10 minifilms (1 per cent). Analysing the data according to race, it was found that the incidence was 0.5 and 1.3 per cent for Lapps and non-Lapps, respectively.

OPERATIVE RESULTS AND THE USE OF THE PROSTHESIS AFTER LOWER LEG AMPUTATIONS

Anders Dahle

Regional Hospital, Trondheim

One hundred and forty nine amputations of the lower extremities in 109 patients were evaluated.

Sixty-one per cent of the patients were males, and 80 per cent were older than 60 years. Indications for amputation were peripheral vascular disease in 76 per cent. Most of the operations were done below-knee.

Twenty-five per cent of the patients died in the hospital.

Wound healing was better the higher the amputation.

About half of the amputees were considered suitable for fitting of a prosthesis, and 10 per cent of these died in the hospital. Eighty-four per cent of the patients used their prosthesis for a shorter or longer time after they left the hospital.

HALO PELVIC TRACTION IN SCOLIOSIS

I. Bjerkreim

Sophus Minde Orthopaedic Hospital, Oslo

Halo-pelvic traction is the most effective method of preoperative traction in the treatment of scoliosis, and the patients can ambulate.

A 6-year-old girl with an infantile idiopathic scoliosis was demonstrated. She was first seen when 9 months old. In spite of conservative treatment the scoliosis progressed, at 4 years it measured 110° , and at 6 years 140° . A halo-pelvic apparatus was applied, and 2 months later the curve had reduced to 57° . A spine fusion from T4 to L3 was then done, using a modified Harrington technique with instruments of small dimension, and the halo-pelvic apparatus was replaced by a Milwaukee brace 10 weeks later. The combination of the halo-pelvic traction and the spine fusion with the Harrington technique reduced the scoliosis curve from 140° to 50° . The patient increased 14 cm in height.

NERVUS INTEROSSEOUS ANTERIOR SYNDROME

Knut Skoghund

Regional Hospital, Trondheim

Three patients with isolated paralysis of the anterior interosseous nerve, which is the largest motor branch of the median nerve, are presented.

The clinical picture was a spontaneous paralysis of *m. flexor pollicis longus* and *m. flexor digitorum profundus* to the index finger in two patients, and an isolated paralysis of the latter in one patient. They all demonstrated a typical thumb-index pinch, with the distal joints of the affected fingers held in hyperextension and the joint proximal to these in increased flexion.

Surgical exploration of the anterior interosseous nerve did not reveal any constrictive structure in relation to the nerve. An external neurolysis was performed in two of the patients, and in all three cases tendon transpositions were done with good functional results.

ARTHRODESIS OF THE KNEE USING TWO PLATES

Olav Nesse

Regional Hospital, Trondheim

Technique The denuded joint is, after compression, fixed with two long vitallium plates, one on each side.

Material Twenty-four cases are reported, six males aged 54 to 73 years, and 18 females aged 49 to 81 years. All had severe destruction of the knee joint with pain, and/or instability and deformity.

Indications Osteoarthritis or post-traumatic arthritis 11, rheumatoid arthritis 8, polyomyelitis 2, tuberculosis 1, osteomyelitis 1, and re-arthrodesis 1.

Results After 4 months there was clinical and roentgenological evidence of fusion, and all patients were pain-free and completely satisfied, except for one who complained of pain related to the plates.

Complications Two patients had thrombosis of lower leg, and one cerebral thrombosis. One wound infection occurred in two

Advantages of the method Free choice of knee position, no external support required. Walking on crutches can be permitted the day after operation, and quick union is achieved.

Oslo, November 19th, 1977

CLINICAL FAT EMBOLISM SYNDROME

Antti Alho

Helsinki University Central Hospital, Helsinki

In a series of 556 patients with multiple injuries, fulminant fat embolism syndrome (FES) was diagnosed in 6 per cent, and a less severe type in 12 per cent of the patients. All FES patients had fractures of the pelvis and long bones, the frequency in the non-FES patients was 54 per

cent. 55 per cent of the FES patients, and 80 per cent of the non-FES patients were hypoxaemic at admission. Various conditions causing post-traumatic pulmonary insufficiency were observed in the latter group.

The management of FES consisted of adequate respiratory care, careful immobilization, and early osteosynthesis of the fractures, and in a selected group, a pharmacological dose of Solu Medrol (10 mg/kg i.v. t.i.d.) during the first day which reduced the signs significantly. The mortality in the whole series was 11 per cent, in the FES patients 6 per cent.

It is concluded that FES complicating fractures is a well-defined entity among the various types of post-traumatic pulmonary insufficiency.

SCREW FIXATION VERSUS PRIMARY PROSTHETIC REPLACEMENT IN ACUTE DISPLACED FEMORAL NECK FRACTURE

Tor Steiner Raugstad, Odd Soreide & Anders Molster

Haukeland Hospital, Bergen

One hundred and four patients with femoral neck fractures were randomized according to birth date. In one-half of the patients the fractures were fixed with von Bahr screws and the other half had the femoral head replaced by a Christensen hemiprosthesis. Full weight bearing was allowed in both groups. The mean operation times were 38 and 86 minutes, respectively.

During the first year mechanical failure occurred in 11 patients with screw fixation. Avascular necrosis of the head of the femur occurred in 2 patients but there were no cases of non union. Dislocation of the prosthesis occurred in 6 patients, and one patient developed deep infection.

The results at the 1-year follow up (Stinchfield classification) were: In the group with screws 52 per cent, respectively. The results are in favour of primary prosthesis.

DIAGNOSIS OF KNEE LIGAMENT INJURIES

Anders Molster, Svein Haukaas & Antti Alho
Haukeland Hospital, Bergen

A series of 51 knee ligament injuries were tested for instability *ad modum* Houghston. Thirty patients were operated on.

Examination under anesthesia was performed in patients who received non-operative treatment even a suspicion of instability could be discerned.

Indication for operation was found in the

..

of 24 triad injuries, and three out of five ulnar and posterior hyperextension injuries. In the operated patient no ligament injury could be found.

It is concluded that careful and repeated pre-operative clinical instability testing gives a correct diagnosis in most knee ligament injuries, and aids planning the operative treatment.

INTERNAL FIXATION OF LUMBAR FRACTURES

Alko
ukeland Hospital, Bergen

fixation of hemipelvic fractures with Hoffmann cotaxis pins in the anterior iliac crests is pain-easing, reduces the lateral opening of the pelvic g and has a haemostatic effect. In these pects it is superior to the pelvic sling. The ne constructions do not, however, effectively interact the cranial dislocation which is an portant factor for residual disability. A double frame with four transversal tie bars is a distractor in the cranial side bar on the side

of dislocation, gave the best reduction, and stability, in a biomechanical laboratory study

Oslo, December 10th, 1977

PRENATAL DEVELOPMENT OF THE HIP JOINT

Per Helland
Central County Hospital Kristiansand

Two different autopsy studies one from India and one from USA, on prenatal development of the hip joint, are compared and discussed.

The degree of anteversion seems to be greater prenatally in normal hips in western countries than in India.

ARTHROSCOPY OF THE KNEE JOINT

Odd Haerum
Central County Hospital, Christiansand

Seventy seven arthroscopies of the knee joint, unsuccessful in eight, are reported.

Subsequent arthrotomy in 62 cases revealed misinterpretation of the arthroscopic findings in nine instances (17 per cent). In the 36 most recently performed arthroscopies the misinterpretation was reduced to 53 per cent. It is concluded that arthroscopy requires skill and experience to obtain maximum benefit.

IN MEMORIAM



Dr Henrich Steffens Nissen-Lie died on May 22nd, after a relatively short illness, at the age of 75 years. After a full and satisfying life, a fine person and a man of outstanding capabilities has passed away.

It is not easy to give an adequate description of Henrich Nissen-Lie in a few words. Superlatives are called for, while at the same time we know that he himself was utterly modest in all ways, including his use of words. This modesty, so characteristic of Nissen-Lie, was in harmony with the other foremost qualities in his personality, unselfishness, absolute integrity and unshakeable resolution. Nissen-Lie endeared himself to all who were privileged to know him and his modesty, steadfastness and compassion made him beloved as a physician. Even in untreatable cases he used his medical prowess to the utmost for the relief and consolation of his patients and won their devotion.

Nissen-Lie graduated in medicine in 1921. He gained a broad experience in orthopaedics and over the years published a series of valuable clinical works. Because of his wide ranging interests in both classic orthopaedics and traumatology he became a bridge-builder between the two fields to the great benefit of Norwegian orthopaedics. He was one of the founding members of the Norwegian Orthopaedic Association and its President from 1953-1955. After service in the Department of Surgery at Ullevål Hospital in the years from 1949-1956 when he was also a lecturer at the University of Oslo, he became chief of staff at Kronprinsesse Marthas Institutt in 1956. Under his leadership, this hospital became a centre for rheumatic and hand surgery and the neurological aspects of orthopaedic surgery in Norway. He was one of the founding members of the Scandinavian Society for Hand Surgery established in 1955. Nissen-Lie was a member of the committee of the Scandinavian Orthopaedic Association and President from 1966-1968. He was a co-editor of *Acta Orthopaedica Scandinavica* from 1966-1972.

For services to Norwegian orthopaedic surgery he was made an honorary member of the Norwegian Orthopaedic Association in 1972, and at an international level he was elected an honorary member of the British Orthopaedic Association in 1968. In 1973 he was knighted (Knight of the Order of St Olav) for his efforts on behalf of orthopaedic surgery. In the same year he retired from Kronprinsesse Marthas Institutt upon reaching retirement age.

Nissen-Lie was for many years an enthusiastic cruising and racing yachtsman and his trophies include a Royal Cup. A fine sportsman, who will also be sadly missed by his yachting colleagues.

May he rest in peace.

Arne Rugtve

Acta Orthopaedica Scandinavica

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Vol 49 Nos. 1-6, 1978

MUNKSGAARD, *Copenhagen*

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Munksgaard
International Booksellers and Publishers Ltd.
35 Nørre Søgade DK-1370 Copenhagen K, Denmark

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Scandinavica

EDITOR: KNUD JANSEN, Copenhagen, Denmark

ACTA ORTHOPAEDICA SCANDINAVICA

is the official publication of the Scandinavian Orthopaedic Association

Acta Orthopaedica Scandinavica publishes original papers on orthopaedic surgery including traumatology. Authors are also invited to publish follow-up notes and comments. Papers previously published in other periodicals are not accepted.

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Business communications, including subscriptions and orders for reprints or advertisements, should be sent to the publishers *Munksgaard International Bookellers and Publishers Ltd.*, 35 Norre Sogade, DK-1370 Copenhagen K, Denmark.

Acta Orthopaedica Scandinavica is published bimonthly. The subscription price per volume of six issues is at present Danish kroner 260.00 plus postage D.kr. 30.00 (US \$ 54.00 £28.75 D.M. 108.75) payable in advance. Prices are subject to exchange rate fluctuation.

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